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ENVIRONMENTAL EFFECTS OF FLUORIDE

GLACIER NATIONAL PARK AND VICINITY

ENVIRONMENTAL PROTECTION AGENCY

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GLACIER NATIONAL PARK AND VICINITY

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Prepared for

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SUMMARY

During the summer and fall of 1970, a study of fluoride accumulation and its pathological effects on many species of flora and fauna was carried out in the areas of Columbia Falls, Montana, and Glacier National Park. The study area included 175 square miles (112,000 acres) within the boundaries of Glacier National Park and 235 square miles (150,000 acres) outside the Park boundaries.

Nineteen sampling zones were designated in the study area. Foliage samples from 16 of the 19 zones yielded, for at least one species of conifer, mean fluoride concentrations higher by a factor of 4 or more than concentrations in foliage from control areas elsewhere in Montana. These 16 sampling zones encompass an area of 375 square miles, or about 90 percent of the study area.

Results of fluoride analyses of other vegetation of species foraged by animals (e.g., grasses and woody shrubs) demonstrated that fluoride accumulation occurs in non-coniferous species as well. Samples of grasses from seven sampling zones, representing more than half of the study area, yielded fluoride concentrations greater than those from control areas by a factor of 2 or more.

Several special studies were made of fluoride accumulation in other than the foliar portions of vegetation species. Results of these studies demonstrated that fluoride accumulates in tissues of pollen, stems, and terminal buds. Thus, fluorides absorbed in plant leaf tissues are not entirely limited to the leaf tissues, as previously believed, but through plant metabolic pathways a portion of the absorbed fluoride moves out of the leaf and into other tissues such as the stems and reproductive tissues.

More than 300 indigenous wild animals were collected in the study area during the 1970 study period. Although species collected were primarily of the rodent family collections of other animals, such as deer, allowed analysis of a fairly good cross-section of herbivores.

Of the animals collected within the boundaries of Glacier National Park the highest concentrations of fluoride were found in those from the southwest corner of the Park. The southwest area of Glacier National Park, as delineated for this study, extended from and included the Apgar Mountains, the lower (southern) portions of Lake McDonald, and the Belton Hills, also known as the Belton Hills Winter Range. This area covers approximately 60 square miles or about 40,000 acres. Chemical analyses of the femurs of the collected animals disclosed that their leg bones had accumulated excessive concentrations of fluoride, in one case 30 times the average concentration of fluoride in control animals of the same species.

Data on fluoride concentrations in bones of animals were analyzed in relation to data on concentrations found in vegetation collected in the same areas. In all cases where fluoride concentrations in animals were high, they were relatively much higher than those in the forage upon which the animals had fed. For instance, fluoride concentrations in coniferous and grass forage in the Apgar Mountains were 2 or 3 times higher than concentrations in control vegetation; in some animals, however, such as the 24 snowshoe hares collected in the Apgar area, fluoride concentrations were almost 20 times higher than those found in snowshoe hares in the control areas. This phenomenon of increasing fluoride concentrations in the food chain was observed in all parts of the study area where above-normal concentrations of fluoride were accumulating in vegetation.

INTRODUCTION

A study of fluoride pollution in Glacier National Park and areas around Columbia Falls, Montana, was initiated at the request of the Superintendent of Glacier National Park during the winter of 1969-70. The study was undertaken by the National Air Pollution Control Administration, now a part of the U.S. Environmental Protection Agency (EPA). Under contract, the author, aided by staff of the Environmental Studies Laboratory at the University of Montana, performed some portions of the research on the effects of fluorides in Glacier National Park and the surrounding southwest areas outside the Park. The major objective of the 1970 study was to ascertain whether fluoride emissions from the reduction plant of the Anaconda Aluminum Company, located at the base of the west side of Teakettle Mountain near Columbia Falls, were accumulating in, and having a detrimental effect upon, the flora and fauna of the Columbia Falls area and Glacier National Park.

Much of the research was carried out by the analytical methods of investigators such as Treshow (1967, 1968, 1970), Adams (1956, 1964, 1969-71), Compton (1965), and Weinstein and McCune (1967-70), who have presented methods to assess fluoride accumulation and necrosis in coniferous foliage and accumulation in other forage species. In an effort to determine the impact of fluoride pollution on the ecology of a national park more completely than these methods allow, some unique studies were also undertaken. Several of these studies can be considered as basic research, yielding results that are new to the scientific literature.

In addition, information gained from parts of the new studies called for re-evaluation of some previously held concepts. It was believed, for example, that gaseous fluorides taken in by the foliage of plants are translocated only to the margin of the leaf in broadleaf species or to the tips of needles in coniferous species. The studies reported here demonstrate that fluorides are translocated and accumulated in other portions of the plant, such as the stem and reproductive tissues. This phenomenon was also reported by Carlson and Dewey (1971) in an independent study of fluoride pollution in the Columbia Falls area.

This report also presents new information on fluoride accumulation in indigenous wild animals. In his review of fluorides, Marier (1971) cites the dearth of information on this subject. Except for the studies of Shupe (1956) on accumulation and effects of fluorides in the bones and teeth of deer, very few studies are available. Considerable information is available on the effects of inorganic fluoride fed to domestic animals in the form of sodium fluoride, but no research is reported on most of the wild animal species examined in this study. For most of these species, therefore, no information is available on pertinent physiological factors, such as urine retention and excretion.

MATERIALS AND METHODS

STUDY AND CONTROL AREAS

Study Area

The area from which vegetation and animal samples were collected during the 1970 study encompasses 410 square miles. It was divided into 19 zones on the basis of preliminary analysis of fluoride accumulation in coniferous species collected in June and early July, 1970. Nine of the collection zones are within the boundaries of Glacier National Park; ten are outside the Park boundaries.

Figure 1 shows the boundaries of each zone on a schematic map of the study area. For ease of identification each zone is also named for a mountain, lake, river, road, or town within its boundaries:

1. West Face of Teakettle Mountain - 12,670 acres
2. Columbia Falls - 36,860 acres
3. Coram - 11,520 acres
4. Lake Five - 9220 acres
5. Columbia Mountain - 5890 acres
6. Desert Mountain - 7680 acres
7. South Fork (Flathead River) - 18,180 acres
8. Middle Fork (Flathead River) - 26,880 acres
9. North Fork (Flathead River) - 17,410 acres
10. Doris Mountain - 4100 acres
11. Headquarters Hill - 2880 acres
12. Belton Hills - 9360 acres
13. Apgar Ridge and Middle Fork Ranger Station - 12,800 acres
14. Apgar Lookout - 3330 acres

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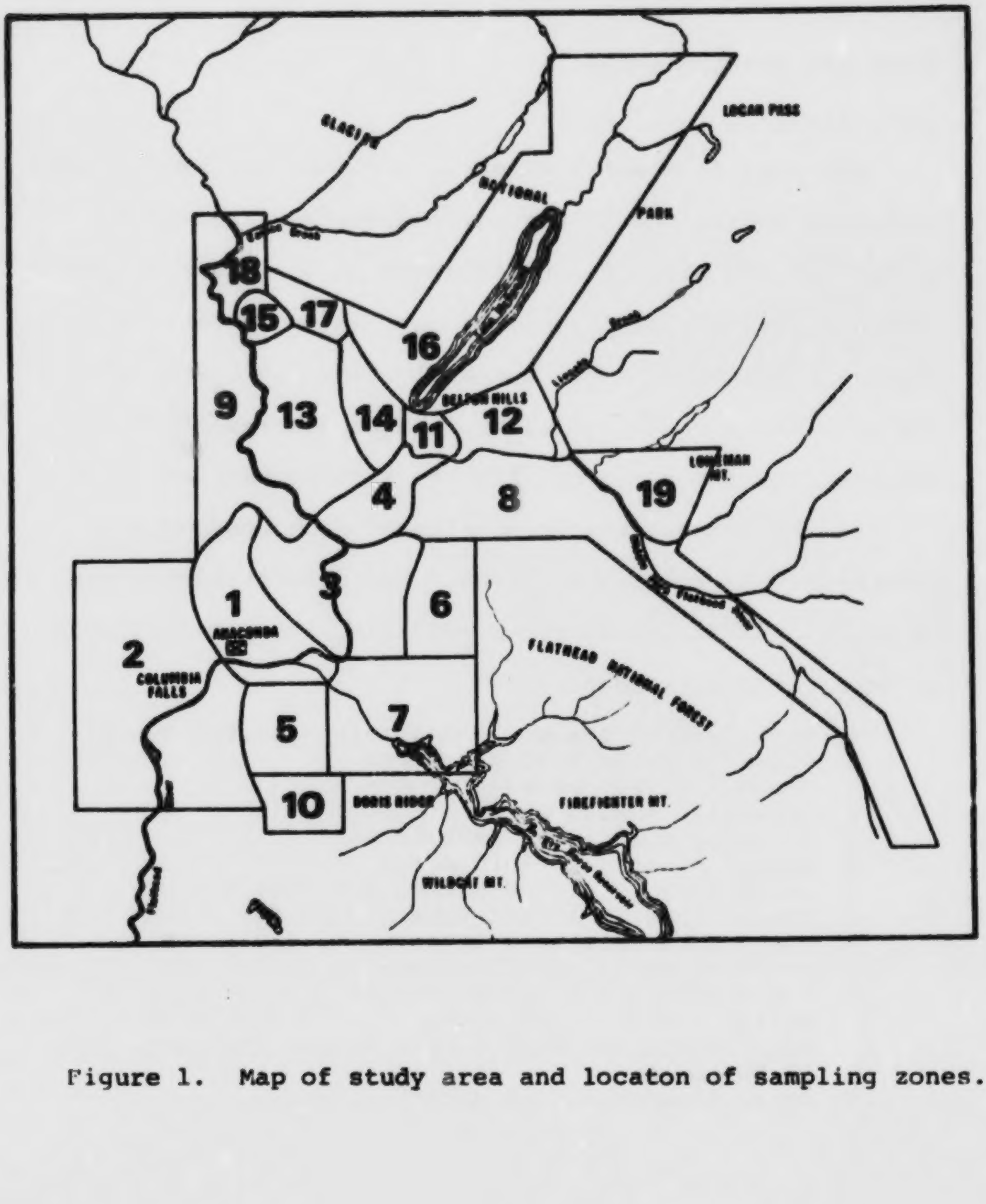

Figure 1. Map of study area and locaton of sampling zones.

15. Boehm's Bear Den - 2880 acres
16. Lake McDonald - 57,860 acres
17. Camas Creek - 8960 acres
18. Huckleberry Mountain - 6400 acres
19. Loneman Mountain - 7680 acres

Zones 1 through 10 are located outside Glacier National Park; zones 11 through 19 are inside the Park. Although the sizes of the zones vary considerably, the concentrations of fluoride accumulated in the vegetation samples collected in each zone were fairly similar.

Control Areas

Species of vegetation and animals identical to those collected in the study area were obtained from several areas of Montana considered to be free from airborne fluoride pollution. These areas, selected to provide control specimens for the study, were 40 to 150 miles distant from Columbia Falls:

Elk Creek
St. Regis
Rogers Pass
Upper St. Mary's Lake
Many Glacier
Swiftcurrent
Twin Creek
Swan Valley
Albert Creek
MacDonald Pass
Rattlesnake Canyon
Pattee Canyon
Swartz Canyon
Pony Lake

Control animals, particularly deer, were collected also from several other locations in Montana remote from Columbia Falls.

COLLECTION, PREPARATION, AND CHEMICAL ANALYSIS OF VEGETATION

Foliage

Most of the vegetation samples collected for chemical analysis in this study were foliage from coniferous species.

Procedures for collecting, preparing, and analyzing foliar samples are described in Appendix F.

With the exception of larch, coniferous trees growing in the Columbia Falls-Glacier National Park area of Montana generally retain 3 years of needle growth. Thus, it was possible to collect 1968, 1969, and 1970 needle growth from most of the trees sampled. Samples from conifers, which bear 3 years of growth, yield more information than samples from deciduous trees and shrubs, which lose their leaves each year. For example, a conifer sample with 3 years of foliage, collected during the first week of July 1970, can indicate:

1. How much fluoride has accumulated in 1 month. The 1970 needles have been exposed to the ambient air for approximately 1 month, depending on topography and location of the tree;
2. How much fluoride has accumulated in 13 to 14 months, as indicated by 1969 needles;
3. How much fluoride has accumulated in 25 to 26 months, as indicated by 1968 needles.

Variation in the length of exposure is very important, since fluoride accumulation depends upon both the concentration of the gaseous fluoride in the ambient air and the duration of exposure.

The fluoride analyses in this study were performed with the use of the Orion fluoride specific ion electrode. Comparison fluoride analyses were also performed by the Autotechnicon semi-automated and other analytical methods. Sample preparation and the electrode measurement method are described in Appendix F. As a check on the accuracy of the fluoride analysis performed in the Environmental Studies Laboratory, duplicate foliage samples were analyzed by as many as four other laboratories using varying analytical methods. Results of the analyses also appear in Appendix F.

Stems

Samples of coniferous stems and stems from some hardwood species were collected in selected zones of the study area. Samples of stem growth for the years 1968, 1969, and 1970 were prepared and analyzed separately. The method of preparing the tissues for fluoride analysis is presented in Appendix F. Since foliage is the receptor of atmospheric fluoride, the purpose of the analyses of stem tissues was to determine whether fluoride is translocated from the needles to other structures of the tree.

Pollen

Coniferous pollen was analyzed for fluoride to test the hypotheses that (a) if the fluoride were translocated from the needle to the stem then it might also be translocated from the stem to the reproductive structures, and (b) in this event the fluoride might be detrimental to the reproductive potential of the species involved. The procedure for preparing pollen for fluoride analysis is presented in Appendix F.

Terminal Buds

Terminal buds are the apical meristematic tissues that develop into stems and needles in conifers, and stems and leaves in hardwoods. Terminal buds of both coniferous and hardwood species were collected and prepared for fluoride analysis. Procedures are presented in Appendix F.

Histological Studies

Before chemical analysis in the laboratory, needles from all coniferous collections from all zones were examined for burned or necrotic tissues. Samples of needles exhibiting such necrosis were removed and prepared separately for histological study. The procedure for preparing conifer needles for histological study is given in Appendix H.

COLLECTION OF ANIMALS AND ANALYSIS OF BONE TISSUE

More than 300 animals were collected within the study area. Most of the specimens collected are classed as herbivores, by definition those that feed almost exclusively on vegetation matter. If fluoride were accumulating in the vegetation of the study area, one could logically assume that it would also be present in the animals that feed upon that vegetation.

The femurs (upper leg bones, hind legs) were removed from all animals collected, and analyzed for fluoride. In some of the larger species, such as deer, other bones were also removed and subjected to fluoride analysis. The method for analysis of bone samples is given in Appendix G.

RESULTS

FLUORIDE ANALYSIS OF CONIFEROUS VEGETATION

Foliage

Approximately 1600 fluoride analyses were completed on coniferous foliage samples collected in the study and control areas. Results of these analyses are presented in Appendix A. The data are summarized in Figures 2 and 3. Average fluoride contents of conifer needles in each area are given by year (age of needle) for ease of comparison with expected normal concentrations. Since the normal concentrations would not be expected to vary with age of needles, it is represented by a single line across the bar graph.

A statistical summary of the data is given in Table 1. Sampling zones are listed in the Table generally in decreasing order of fluoride concentration in the foliage, first for the zones located outside Glacier National Park, then for those located within the Park. Data from analyses of the control vegetation are summarized in the final section of the Table.

Within Table 1 for each sampling zone, conifer species, and year of needle growth are listed the mean fluoride concentrations for all foliage samples, the maximum fluoride

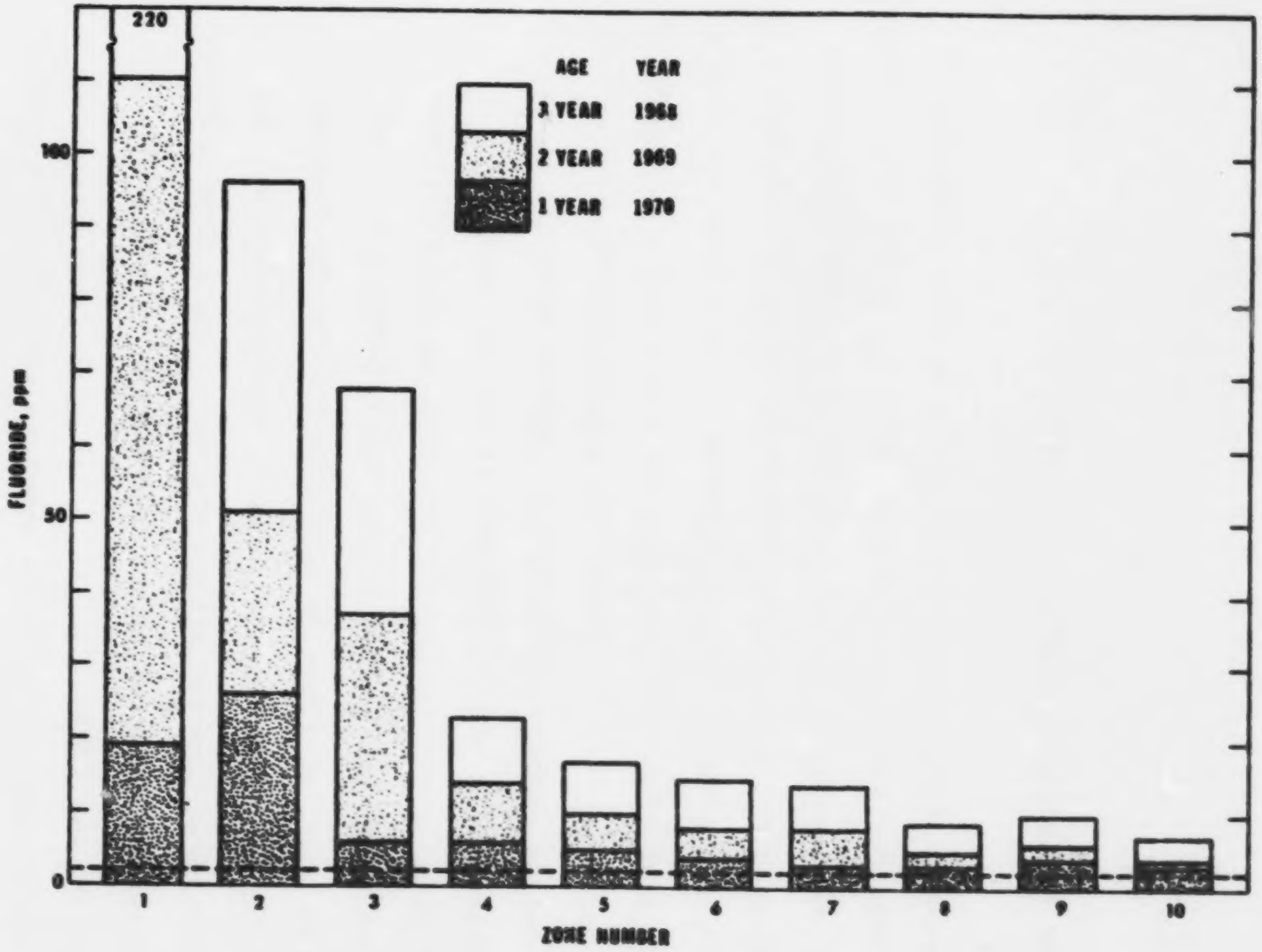

Figure 2 Average conifer foliage fluoride content outside Glacier National Park.

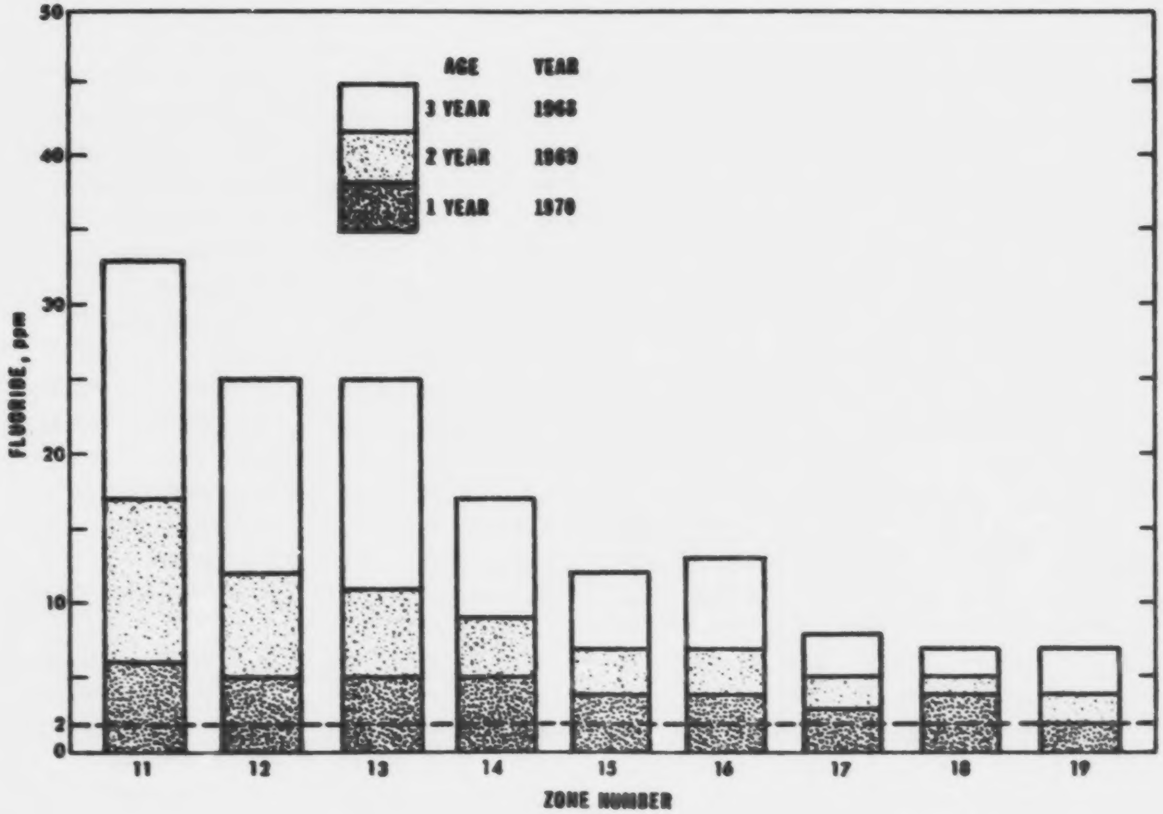

Figure 3 Average conifer foliage fluoride content in Glacier National Park.

TABLE 1. FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE

(ppm by weight in dry needles)

		Lodgepole pine			Ponderose pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
West Face Teakettle Mountain Zone No. 1	No. samples	13	13	13	4	5	5	7	7	7			
	Mean	310.3	146.4	19.4	211.0	116.2	22.2	140.4	75.4	14.7			
	Maximum	668	345	61.8	410	292	43.0	225	125	26.0			
	Minimum	33	13.5	3.9	105	31.0	4.5	37.0	23.0	7.4			
	Std. dev.	212	109	18.4	138	104	16.4	75.5	33.8	6.3			
	95 Percentile	688	341	52.3	536	338	57.2	287	141	26.9			
	99 Percentile	879	439	68.7	838	506	83.7	378	182	34.5			
Columbia Falls Zone No. 2	No. samples	6	7	7	28	28	28				22	22	22
	Mean	76.5	36.3	16.9	97.1	50.7	24.0				114.2	65.8	38.9
	Maximum	116	54.0	31.0	192	96.0	52.4				182	110	78.0
	Minimum	30.6	19.2	10.8	18.2	11.5	5.0				32.8	24.8	18.2
	Std. dev.	31.8	12.6	6.7	41.3	22.4	10.7				46.5	24.1	14.7
	95 Percentile	141	60.8	29.9	167.4	88.8	42.2				194	107	62.1
	99 Percentile	184	75.9	38.0	199	106	50.5				231	126	73
Coram Zone No. 3	No. samples	32	32	32	12	13	13	16	16	16	2	2	1
	Mean	90.0	47.5	7.6	47.0	19.8	4.9	60.9	40.2	10.0	73.5	39.0	3.5
	Maximum	520	260	20.5	120	41.0	13.5	225	90.0	23.0	93.0	49.0	
	Minimum	24.0	13.5	3.9	16.0	10.0	2.6	12.8	14.9	3.9	54.0	29.0	
	Std. dev.	119.3	56.2	4.1	28.3	9.0	3.3	49.6	24.5	5.6	27.6	14.1	
	95 Percentile	292	143	14.5	97.8	35.8	10.8	148	83.1	19.8	248	128	
	99 Percentile	379	183	17.5	124	43.9	13.7	190	104	24.6	952	488	

TABLE 1 (continued). FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE

(ppm by weight in dry needles)

		Lodgepole pine			Ponderosa pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
Lake Five Zone No. 4	No. samples	15	14	15	8	8	8				1	1	1
	Mean	26.3	13.1	5.1	20.6	12.4	4.0				23.0	17.0	7.3
	Maximum	38.0	21.8	8.2	26.0	16.5	5.8						
	Minimum	19.0	7.0	3.1	14.0	9.9	2.3						
	Std. dev.	6.1	4.2	1.3	3.7	2.5	1.3						
	95 Percentile	37.0	20.5	7.4	27.6	17.1	6.46						
	99 Percentile	42.3	24.2	8.5	31.7	19.9	7.90						
Columbia Mountain Zone No. 5	No. samples	5	5	5	6	6	6	9	9	9	1	1	1
	Mean	8.6	4.2	2.7	40.5	21.4	9.2	5.9	4.8	3.4	14.0	8.3	6.3
	Maximum	14.2	5.5	3.7	79.0	38.5	18.5	14.5	7.3	7.0			
	Minimum	3.4	2.7	2.0	7.9	7.6	4.5	3.5	3.4	1.5			
	Std. dev.	5.0	1 2	0.7	34.2	14.9	5.1	3.4	1.4	1.6			
	95 Percentile	19.3	6 [illegible]	4.2	109.4	51.4	19.5	12.2	7.4	6.4			
	99 Percentile	27.3	8.7	5.3	155.6	71.5	26.4	15.7	8.9	8.0			
Desert Mountain Zone No. 6	No. samples	9	9	9	13	13	13	8	8	8			
	Mean	17.6	7.8	4.1	17.7	8.3	3.6	11.0	7.5	3.8			
	Maximum	34.0	18.0	7.6	30.5	13.0	7.0	21.0	12.0	5.5			
	Minimum	6.5	2.7	1.5	7.4	3.7	1.9	4.3	4.0	1.8			
	Std. dev.	9.7	4.5	2.3	7.1	3.5	1.5	5.3	2.9	1.2			
	95 Percentile	35.6	16.2	8.4	30.4	14.5	6.3	21.0	13.0	6.0			
	99 Percentile	45.7	20.8	10.8	36.7	17.7	7.6	26.9	16.2	7.3			

TABLE 1 (continued). FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE
(ppm by weight in dry needles)

		Lodgepole pine			Ponderose pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
South Fork Zone No. 7	No. samples	3	3	3	7	7	7	7	7	7			
	Mean	18.0	9.2	2.7	16.0	9.6	4.0	9.6	6.2	3.6			
	Maximum	33.0	17.0	4.5	26.0	15.0	7.5	15.0	9.1	6.3			
	Minimum	6.4	3.8	1.6	3.9	2.9	2.7	3.6	2.4	1.6			
	Std.dev.	13.6	6.9	1.6	8.2	4.4	1.6	4.7	2.7	1.8			
	95 Percentile	57.7	29.3	7.4	31.9	18.1	7.1	18.7	11.4	7.1			
	99 Percentile	112.7	57.2	13.8	41.8	23.4	9.0	24.4	14.7	9.3			
Middle Fork Zone No. 8	No. samples	10	10	10				3	3	3			
	Mean	13.5	6.7	3.8				4.3	3.4	2.5			
	Maximum	29.5	11.0	5.2				5.2	3.7	3.5			
	Minimum	3.2	3.2	2.5				3.5	3.0	1.7			
	Std. dev.	9.7	2.7	0.7				0.9	0.4	0.9			
	95 Percentil	31.3	11.6	5.1				6.9	4.6	5.1			
	99 Percentil	40.9	14.3	5.8				10.6	6.2	8.8			
North Fork Zone No. 9	No. samples	11	11	11	2	2	2	10	10	10			
	Mean	11.0	5.7	4.1	9.5	6.4	3.9	10.2	6.3	5.2			
	Maximum	20.5	9.7	7.2	11.0	7.0	4.0	14.0	9.0	9.0			
	Minimum	4.8	3.3	2.4	8.0	5.8	3.7	5.6	4.3	3.1			
	Std. dev.	4.5	1.9	1.3	2.1	0.8	0.2	3.3	1.7	1.8			
	95 Percentile	19.2	9.14	6.5	22.8	11.5	5.2	16.2	9.4	8.5			
	99 Percentile	23.4	11.0	7.7	76.3	31.9	10.3	19.5	11.1	10.3			

TABLE 1 (continued). FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE

(ppm by weight in dry needles)

		Lodgepole pine			Ponderosa pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
Doris Mountain Zone No. 10	No. samples	4	4	4	8	8	8	6	6	6			
	Mean	4.5	2.7	3.5	11.5	6.1	3.7	4.5	3.6	2.7			
	Maximum	6.2	3.4	7.8	44.5	14.5	6.7	5.5	4.1	4.2			
	Minimum	3.2	2.2	1.5	3.5	2.5	1.7	3.9	2.6	2.0			
	Std. dev.	1.3	0.5	2.9	13.9	4.1	1.6	0.7	0.5	0.8			
	95 Percentile	7.6	3.9	10.3	37.8	13.9	6.7	5.9	4.6	4.3			
	99 Percentile	10.4	5.0	16.7	53.2	18.4	8.5	6.9	5.3	5.4			
Headquarters Hill Zone No. 11	No. samples	13	13	13	10	10	10	5	5	5	2	2	2
	Mean	30.8	14.3	5.1	28.9	17.7	4.3	22.7	13.9	4.7	51.0	21.7	8.0
	Maximum	42.0	21.3	9.8	40.0	26.0	8.7	31.0	29.0	6.4	54.0	24.4	12.0
	Minimum	20.5	7.0	2.3	20.5	13.0	2.0	14.0	6.9	3.0	48.0	19.0	4.0
	Std. dev.	7.0	3.6	2.3	6.4	3.9	2.1	6.7	8.8	1.2	4.2	3.8	5.7
	95 Percentile	42.9	20.5	9.1	40.6	24.8	8.2	37.0	32.7	4.7	77.5	45.7	44.0
	99 Percentile	49.6	24.0	11.3	47.0	28.7	10.2	47.8	46.9	9.2	184.6	142.6	189.4
Dalton Hills Zone No. 12	No. samples	15	15	15	5	5	5	5	5	5			
	Mean	30.0	12.7	4.8	29.2	14.6	4.5	15.7	9.5	5.2			
	Maximum	40.0	17.5	6.7	39.0	19.0	6.7	22.0	12.5	8.6			
	Minimum	16.3	6.4	1.9	16.0	10.4	3.1	8.3	5.0	1.5			
	Std. dev.	7.5	3.9	1.4	8.7	3.8	1.4	4.9	3.2	2.5			
	95 Percentile	43.2	19.6	7.3	47.7	22.7	7.5	26.1	16.3	10.5			
	99 Percentile	49.7	22.9	8.5	61.8	28.8	9.8	34.1	21.5	14.6			

TABLE 1 (continued). **FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE**

(ppm by weight in dry needles)

		Lodgepole pine			Ponderose pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
Apgar Ridge and NFRS Zone No. 13	No. samples	14	14	14	13	14	14	7	7	7			
	Mean	31.0	12.4	4.6	26.7	13.3	4.2	16.0	8.5	5.8			
	Maximum	59.0	23.0	7.7	51.0	27.0	7.5	23.0	13.0	8.0			
	Minimum	10.0	3.3	2.3	15.0	7.1	2.5	9.1	6.0	2.3			
	Std. dev.	15.0	6.7	1.8	9.0	5.5	1.5	4.8	2.3	1.9			
	95 Percentile	57.6	24.3	7.8	42.7	23.0	6.9	25.3	13.0	9.5			
	99 Percentile	70.8	30.2	9.4	50.8	27.9	8.2	33.8	17.0	12.8			
Apgar Lookout Zone No. 14	No. samples	15	15	15	5	5	5	2	2	2			
	Mean	18.9	9.1	4.4	23.5	13.5	6.6	8.9	5.5	3.0			
	Maximum	28.0	17.0	15.0	36.5	28.9	16.4	12.0	6.3	3.3			
	Minimum	11.0	4.6	1.4	18.0	9.0	2.9	5.8	4.6	2.6			
	Std. dev.	5.5	3.1	3.1	7.4	8.6	5.6	4.4	1.2	0.5			
	95 Percentile	28.6	14.6	9.9	39.3	31.8	18.5	36.7	13.1	6.2			
	99 Percentile	33.3	17.2	12.5	51.2	45.7	27.6	148.9	43.7	18.9			
Boehm's Bear Den Zone No. 15	No. samples	5	5	5	1	1	1	9	9	9			
	Mean	22.5	10.6	4.2	6.9	4.5	2.7	7.5	5.7	4.1			
	Maximum	45.0	22.0	6.5				16.0	7.4	6.2			
	Minimum	8.2	2.8	3.2				4.3	4.3	1.8			
	Std. dev.	14.4	7.3	1.4				3.8	1.1	1.6			
	95 Percentile	53.2	26.2	7.2				14.6	7.8	7.1			
	99 Percentile	76.4	38.0	9.5				18.5	8.9	8.7			

TABLE 1 (continued). FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE

(ppm by weight in dry needles)

		Lodgepole pine			Ponderosa pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
Lake McDonald Zone No. 16	No. samples	11	11	11				29	29	29			
	Mean	14.1	7.2	3.2				11.5	7.1	4.4			
	Maximum	28.0	14.0	5.4				24.4	17.0	8.3			
	Minimum	5.3	2.9	1.8				2.9	2.8	<1.0			
	Std. dev.	7.3	4.1	1.2				5.6	3.5	1.5			
	95 Percentile	27.3	14.6	5.4				21.0	13.1	7.0			
	99 Percentile	34.3	18.5	6.5				25.3	15.7	8.1			
Camas Creek Zone No. 17	No. samples	6	6	6	1	1	1	3	3	3			
	Mean	8.3	4.7	3.0	9.1	4.3	2.5	6.7	5.0	3.6			
	Maximum	11.0	8.5	3.8				9.3	7.1	4.8			
	Minimum	4.8	2.9	1.6				2.8	1.4	1.9			
	Std. dev.	2.1	2.0	0.9				3.4	3.1	1.5			
	95 Percentile	12.5	8.7	4.8				16.6	14.1	8.0			
	99 Percentile	15.4	11.4	6.0				30.4	26.6	14.1			
Huckleberry Mountain Zone No. 18	No. samples							6	6	6			
	Mean							7.0	4.7	3.5			
	Maximum							12.5	8.0	6.4			
	Minimum							3.8	1.4	1.5			
	Std. dev.							3.0	2.4	1.9			
	95 Percentile							13.0	9.5	7.3			
	99 Percentile							17.1	12.8	9.9			

TABLE 1 (continued). FLUORIDE CONCENTRATIONS IN CONIFEROUS FOLIAGE

(ppm by weight in dry needles)

		Lodgepole pine			Ponderose pine			White pine			Douglas fir		
		1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
Loneman Mountain Zone No. 19	No. samples	3	3	3	2	2	2	6	6	6			
	Mean	5.6	3.5	2.1	8.8	4.8	2.0	5.3	4.6	2.7			
	Maximum	7.0	4.3	2.6	9.6	5.4	2.4	8.5	6.2	3.4			
	Minimum	3.6	2.9	1.5	7.9	4.3	1.6	3.1	2.2	1.7			
	Std. dev.	1.8	0.7	0.6	1.2	0.8	0.6	2.5	1.4	0.6			
	95 Percentile	10.9	5.5	3.9	16.4	9.9	5.8	10.3	7.4	3.9			
	99 Percentile	18.1	8.4	6.3	47.0	30.3	21.1	13.7	9.3	4.8			
ALL CONTROLS	No. samples	14	14	14	9	9	9	4	4	4	4	4	4
	Mean	2.2	2.6	2.1	2.6	2.2	2.0	1.8	1.9	1.8	2.1	2.6	1.6
	Maximum	3.9	5.2	4.5	5.0	3.7	2.7	3.0	3.0	2.5	2.9	4.1	1.8
	Minimum	1.0	1.0	1.0	1.1	1.2	1.1	1.1	1.1	1.1	1.7	1.5	1.5
	Std. dev.	1.1	1.1	1.0	1.3	0.9	0.6	0.8	0.9	0.6	0.6	1.2	0.2
	95 Percentile	4.2	4.6	3.9	5.0	3.9	3.1	3.7	4.0	3.2	3.5	5.4	2.0
	99 Percentile	5.1	5.5	4.8	6.4	4.8	3.7	5.4	6.0	4.5	4.8	8.0	2.5

concentration and the minimum concentration. The 95th and 99th percentiles were calculated using Student's t-distribution. This was necessary because of the small number of observations in some of the samples. When the sample size is small, the estimated 95th and 99th percentile values may exceed the measured maximum concentration. Of the 1446 samples, fluoride concentrations in 57 exceeded the calculated 95th percentile (73 would be expected) and 11 exceeded the calculated 99th percentile (14 or 15 would be expected). Of the 11 samples that exceeded the calculated 99th percentile, 6 are from lodgepole pine in sampling zone 3; results for this species in this zone appear to be bimodal.

The maximum concentration of fluoride in vegetation permitted under Montana State Regulations is 35 ppm. The maximum measured fluoride concentrations, for at least one sample, exceeded this limit in samples from 11 of the 19 sampling zones:

West Face of Teakettle Mountain
Columbia Falls
Coram
Lake Five
Columbia Mountain
Doris Mountain
Headquarters Hill
Belton Hills
Apgar Ridge and Middle Fork Ranger Station
Apgar Lookout
Boehm's Bear Den

The last five listed zones are within the boundary of Glacier National Park.

One or more of the calculated 95th percentile concentrations, likewise, exceed the Montana standard in 13 sampling zones; one or more of the calculated 99th percentile concentrations exceed the standard in 16 zones. Only sampling zones 16, 17, and 19 failed to yield one or more 99th percentile values greater than the Montana standard for fluoride in forage.

Burnt or necrotic needles were obtained from pine species at 40 sites within the study area for the purpose of histological study. Twenty-two of the sites from which partially necrotic pine needles were selected were located within the boundaries of Glacier National Park. Although at the time of selection, no information was available on how much fluoride had accumulated in these needles, every needle collection analyzed showed the specific disease syndrome that is manifested by conifer needle tissues that have been exposed to excessive atmospheric fluorides.

Selected specimens of the three major species of pine, each manifesting the fluoride-caused disease syndrome, were subjected to chemical analysis for fluoride with the following results:

1. 1969 Ponderosa pine needles collected in the Apgar Ridge and MFRS zone (collection number 166 at 3900 feet elevation) contained 27 ppm of fluoride.
2. 1969 lodgepole pine needles collected in the Headquarters Hill zone (collection number 97 at 4600 feet elevation) contained 17.5 ppm of fluoride.
3. 1969 white pine needles collected in the Belton Hills zone (collection number 151 at 4580 feet elevation) contained 12.5 ppm of fluoride.

These concentrations of fluoride are based on analysis of the whole needle; concentrations would, of course, have been much higher if only the burnt tips had been analyzed. These results demonstrate, however, that at fluoride levels only 2 or 3 times higher than the normal fluoride background in healthy trees, tissue necrosis does occur.

Stems

Samples of conifer stems were collected in the late fall and winter of 1970 after seasonal rains and snowfall had occurred in the study area. Some stems were washed in the laboratory before analysis; others were left unwashed. Results of the analyses are presented in Table 2. For the 15 samples from three southwestern zones of Glacier National Park the difference between average fluoride concentrations in coniferous stems that had been washed and average concentrations in and on coniferous stems that were left unwashed was 1.2 ppm of fluoride. This slight difference indicates that very little or no particulate fluoride such as aluminum fluoride, cryolite, or sodium fluoride was being retained on conifers growing in Glacier National Park. Similar analyses of washed and unwashed conifer stems from control areas yielded an average difference in fluoride concentration of about 0.5 ppm. These slight differences between concentrations in washed and unwashed stems of control vegetation may be attributed to soil particles containing fluoride being blown by winds and lodging on the rough bark surface of conifer

Table 2. FLUORIDE CONCENTRATIONS IN WASHED AND UNWASHED CONIFER STEMS

Sampling zone	No. samples	Fluorides, ppm by weight					
		1968 Stems		1969 Stems		1970 Stems	
		washed	Un-washed	washed	Un-washed	washed	Un-washed
Columbia Falls Zone 2	12	8.0	13.0	9.3	14.2	11.0	14.0
Coram, Zone 3	8	6.3	7.0	6.0	7.7	7.2	8.5
Glacier Park Zones 11, 12, 13	15	5.2	6.5	5.8	7.1	6.0	7.0
Controls	11	3.7	4.1	4.0	4.6	4.0	4.6

stems. Such particles are expected to be dislodged by the agitation and washing procedures and to account for the 0.5 ppm difference in fluoride readings.

The average fluoride concentrations found in washed 1968, 1969, and 1970 conifer stems collected from Belton Hills, Apgar Ridge and MFRS, and Headquarters Hill, of Glacier National Park, were 5.2 ppm, 5.8 ppm, and 6 ppm, respectively. By comparison, the average fluoride concentrations in washed coniferous stems from control areas for the same years' growth were 3.7 ppm, 4.0 ppm, and 4.0 ppm, respectively. Thus, there was no noteworthy increase or decrease in fluoride concentrations in washed coniferous stems from the Glacier National Park zones or the control areas during the 2-1/2 year period.

The analysis of washed and unwashed stems demonstrates that fluoride is being retained in and on the various years' stem growth, but the concentrations tend to decrease slightly each year, perhaps as a result of leaching from the weather and/or the increase in volume of older tissues. The results of these analyses also show that fluoride concentrations were approximately twice as great in washed stems from Columbia Falls as in washed stems from the Glacier National Park zones, and that the concentrations in stems from the Glacier National Park zones were 1-1/2 times the concentrations in stems from control areas.

Because the bark cannot be removed from coniferous stems without removing large portions of the active tissue of the inner stem, separate analyses of the outer bark and of the inner bark and cambial tissues of conifers were not undertaken. Since such separation is possible in hardwoods, samples from various hardwood species were obtained and separate analyses were performed on these tissues. The average fluoride concentrations of washed and unwashed tissues from the stems of three species of hardwood collected in selected sampling zones and in control areas are given in Table 3. Results are presented for three different series of stem tissue:

1. Bark and cortex
2. Cortex, phloem, cambium, and active xylem
3. Core (xylem and pith)

The results of fluoride analysis of unwashed bark demonstrate that high concentrations of fluoride particulate were present on hardwood stems from the West Face of Teakettle Mountain zone. Concentrations of fluoride particulate on unwashed hardwood stems were lower in samples from the Columbia Falls zone 4-1/2 miles to the west, and were much lower in samples from the Coram zone 6-1/2 miles to the east. Very little particulate was found on hardwood stems from the Glacier National Park zones; concentrations were comparable to those found on coniferous stems.

Average fluoride concentrations found in the washed bark and cortex were similar in hardwood samples collected from the Teakettle Mountain, Columbia Falls, and Coram zones (8.5 to 7.5 ppm). Average fluoride concentrations in washed samples from the Glacier National Park zones were slightly lower, but still were twice as high as the average for washed samples from the control areas.

Table 3. FLUORIDE CONCENTRATIONS IN WASHED AND UNWASHED TISSUES FROM 1970 HARDWOOD STEMS

Sampling zone	Bark and cortex		Phloem, cambium, outer xylem		Xylem and pith	
	HCl washed	un-washed	HCL washed	un-washed	HCl washed	un-washed
Teakettle Mountain Zone 1	8.5	44.0	7.2	8.4	2.8	3.6
Columbia Falls Zone 2	7.9	25.3	6.8	7.1	3.2	3.1
Coram Zone 3	7.5	8.2	6.2	6.5	3.1	2.8
Glacier Park Zones 11, 12, 13	6.4	8.5	5.8	8.5	2.9	3.2
Controls	3.2	4.6	2.9	4.6	3.0	2.6

Fluoride concentrations in the inner active tissue of hardwoods (phloem, cambium, and outer xylem) from the study area were about twice as high as concentrations in similar inner stem tissues of hardwoods from control areas. Average fluoride concentrations in core tissues (xylem and pith) of the stems of all samples taken from the study area and from the control zones are similar and are low (2.6 to 3.6 ppm).

Pollen

Samples of conifer pollen were collected from 14 of the 19 sampling zones and analyzed for fluoride content. Samples of pollen obtained from control areas were also analyzed. Results of pollen analyses are given in Appendix B and are summarized in Table 4.

The mean fluoride concentration for seven pollen samples from control areas is 3.8 ppm. The mean fluoride concentrations in pollen samples from nine of the 14 study area zones sampled are greater than the means for control samples by a factor of 2 or more.

Four of the nine sampling zones that yielded high fluoride concentrations in pollen are within Glacier National Park. The average fluoride concentration in 14 samples taken from these four zones (Apgar Ridge and MFRS, Headquarters Hill, Lake McDonald, and Belton Hills in the southwest portion of Glacier National Park) was 11.9 ppm, approximately 3 times greater than the average fluoride concentration found in pollen from control conifers.

Table 4. FLUORIDE CONCENTRATIONS IN CONIFEROUS POLLEN

Sampling zone	No. samples	Fluoride, ppm by weight		
		Mean	Maximum	Minimum
1. Teakettle Mountain	4	23.2	32.0	13.7
3. Coram	8	12.0	16.0	8.0
4. Lake Five	3	15.6	19.8	11.0
5. Columbia Mountain	2	6.2	7.3	5.1
6. Desert Mountain	1	19.5		
8. Middle Fork	8	5.6	8.0	1.7
9. North Fork	3	8.1	9.2	6.4
11. Headquarters Hill	6	14.3	18.0	10.0
12. Belton Hills	1	13.3		
13. Apgar Ridge and MFRS	3	12.0	17.8	6.1
15. Boehm's Bear Den	3	5.6	8.4	3.0
16. Lake McDonald	4	7.8	10.0	6.0
17. Camas Creek	2	4.8	5.7	3.8
18. Huckleberry Mountain	2	4.2	6.6	1.9
Controls	7	3.8	5.5	1.7

In three northern zones of Glacier National Park (Huckleberry Mountain, Boehm's Bear Den, and Camas Creek) the average fluoride concentration in pollen was 5.0 ppm; the highest concentration found in any sample was 8.4 ppm. These values are similar to those for pollen from control areas.

Collections of conifer pollen from the Coram zone were all made on the lower slopes of the east side of Teakettle Mountain, close to the Blankenship Ridge area on the North Fork of the Flathead River. The average fluoride concentration in conifer pollen from this area was 12 ppm, similar to the concentration found in pollen from the southwest zones of Glacier National Park.

The average fluoride concentration in conifer pollen samples collected in the Columbia Falls zone was 23.2 ppm, approximately 5 times greater than the concentration found in pollen from control areas.

Excessive fluoride concentrations in conifer pollen from the southwestern zones of Glacier National Park, for which comparisons of washed and unwashed stems indicate that fluoride content is not surface particulate, apparently accumulated from the gaseous fluoride. One may reason further that the fluoride in pollen probably came via the leaf tissues, since the pollen is not exposed to the ambient air during microsporogenesis within the staminate cone.

Terminal Buds

A small project was undertaken to determine fluoride concentrations in coniferous terminal buds (the next year's stem and needle primordia) collected from trees in selected zones in the study area and in control areas. Results of fluoride analysis of unwashed and washed terminal buds are tabulated in Appendix C and are summarized in Table 5.

Results for the western Columbia Falls zone indicate that approximately half of the fluoride was on the outside of the buds, presumably in the form of particulate capable of removal by washing. The average fluoride concentrations found in unwashed and washed terminal buds from the Columbia Falls zone were 10.5 and 5.9 ppm, respectively.

Average fluoride concentration in unwashed terminal buds of conifers collected from the southwestern zones of Glacier National Park was 3.9 ppm; the average for washed terminal buds was 2.9 ppm. Concentrations in unwashed and washed terminal buds from control areas were similar (3.2 and 2.4 ppm, respectively) to those from the Glacier National Park zones.

It should be noted that the terminal buds of conifers analyzed for fluoride from the Glacier National Park zones were collected in July, whereas those from the Columbia Falls zone and control areas were collected in the Fall (October and November) of 1970. Thus, the possible fluoride translocations from leaf to terminal bud are not comparable because of the 3 to 4 month difference in collecting time.

Table 5. FLUORIDE CONCENTRATIONS IN CONIFEROUS TERMINAL BUDS, 1970

Sampling zone	Washed samples		Unwashed samples	
	No. samples	Fluoride, ppm	No. samples	Fluoride, ppm
West Columbia Falls Zone 2	22	5.9	22	10.5
East Columbia Falls Zone 2	5	9.3	3	10.1
South Fork Zone 7	2	3.7	1	7.0
Glacier National Park Zones 11, 12, 13	3	2.9	5	3.9
Controls		2.4		3.2

Grass

Approximately 100 samples of grass and hay were collected in the study area during the 1970 study period. Data from fluoride analyses of these samples are presented in Appendix D and are summarized in Table 6. The highest fluoride concentrations in grass samples were found in collections from the Columbia Falls and West Face of Teakettle Mountain zones. High fluoride concentrations (about twice the control value) were found in 10 of the 18 zones sampled, four of them within the boundary of Glacier National Park. It should be noted, however, that concentrations in the grass samples from the four zones within Glacier National Park were only approximately twice as high as those from control areas. Of the 25 samples collected from the Teakettle Mountain and Columbia Falls zones, 23 showed fluoride concentrations greater than the State of Montana standard of 35 ppm; concentrations in one sample from the Columbia Falls zone exceeded the standard by a factor of almost 12.

FLUORIDE ANALYSIS OF SOILS

Results of fluoride analysis of soil samples collected from 11 of the 19 sampling zones appear in Table 7. Analysis of soils from a control area, MacDonald Pass, yielded a fluoride concentration of 250 ppm, higher than or similar to those found in soils from 9 of the 11 zones in the study area; only for the Lake Five and Teakettle Mountain zones were concentrations significantly higher. Fluoride con-

Table 6. FLUORIDE CONCENTRATIONS IN GRASS, 1970

Sampling zone	No. samples	Fluoride, ppm by dry weight			
		Mean	Maximum	Minimum	Std. dev.
1. Teakettle Mountain	6	87.4	275.0	16.2	96.3
2. Columbia Falls	19	149.1	410.0	48.0	94.4
3. Coram - grass	12	14.7	64.0	4.5	16.5
- hay	6	12.9	20.0	5.8	5.1
4. Lake Five	3	5.4	7.4	2.7	2.4
5. Columbia Mountain	1	14.0			
6. Desert Mountain	5	5.6	11.0	1.8	3.9
7. South Fork	3	7.1	10.0	4.8	2.6
8. Middle Fork	10	4.0	7.3	1.0	2.2
9. North Fork	7	6.3	9.3	2.7	2.3
10. Doris Mountain	1	3.8			
11. Headquarters Hill	4	7.7	12.3	4.4	3.4
12. Belton Hills	3	10.2	17.5	6.5	6.3
13. Apgar Ridge and MFRS	3	7.8	12.5	2.8	4.8
14. Apgar Lookout	3	4.8	11.0	1.6	5.3
15. Boehm's Bear Den	4	2.8	5.3	1.0	1.8
16. Lake McDonald	7	10.4	26.5	2.7	8.0
17. Camas Creek	5	5.1	6.2	3.6	1.0
19. Loneman Mountain	2	4.6	5.8	3.4	1.7
Controls	16	4.4	7.8	2.0	1.7

Table 7. FLUORIDE CONCENTRATION IN SOILS, SINGLE SAMPLES

Sampling zone	Fluoride, ppm
1. Teakettle Mountain	540
2. Columbia Falls	168
3. Coram	217
4. Lake Five	408
7. South Fork	245
8. Middle Fork	235
9. North Fork	113
11. Headquarters Hill	235
12. Belton Hills	245
13. Apgar Ridge and MFRS	118
14. Apgar Lookout	275
Control (MacDonald Pass)	250

centrations for all samples may be considered within normal limits for soil according to Marier (1971).

FLUORIDE ANALYSIS OF ANIMAL SPECIMENS

Approximately 330 animal specimens were collected from the study area and bones were analyzed for fluoride content. Results of these analyses are given in Appendix E. Data representing five animal species are summarized graphically in Figure 4, with indication of the expected normal concentrations. Data on all species collected are summaried in Table 8.

In all species except two, the average fluoride concentrations found in the femur bones of control animals were below 200 ppm. The only control species for which the average fluoride concentration in femur bones exceeded 200 ppm were deer and grouse, with averages of 225 and 209 ppm, respectively. In general, for over 400 indigenous wild animals collected in control areas of Montana in past years, analysis indicates that concentrations of fluoride in femur bones rarely exceeded 250 ppm.

Animals were collected from 17 of the 19 sampling zones of the study area; the Doris Mountain and Huckleberry Mountain zones were excluded. In all zones sampled, mean fluoride concentrations in femur bones of animal specimens exceeded those for control animals of the same species. Further, the ratio of fluoride concentrations in bones of animals from the study area to those in bones of animals from control areas was in all cases greater than the ratio of fluoride

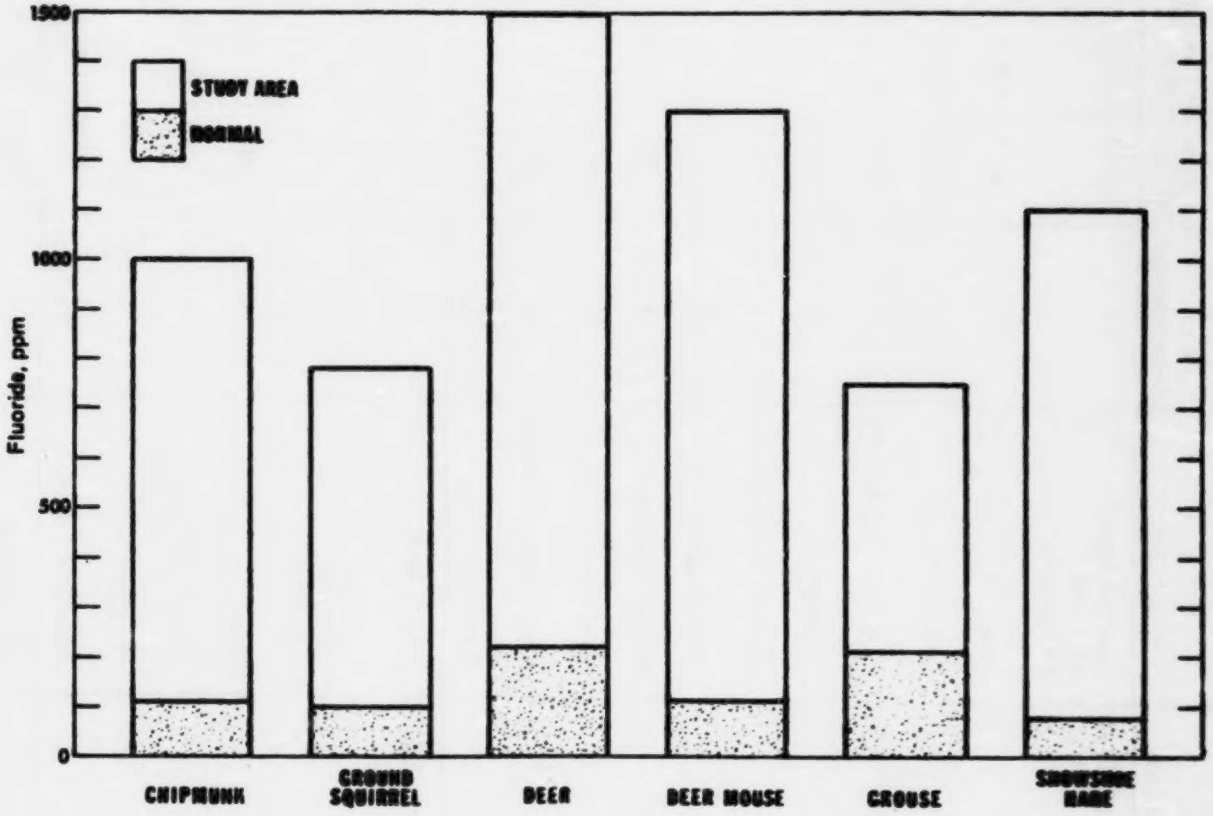

Figure 4 Average bone fluoride content.

Table 8. FLUORIDE CONCENTRATION IN FEMUR BONES OF INDIGENOUS WILD ANIMALS

Sampling zone	Species	No. Specimens	Fluoride, ppm by weight		
			Mean	Max.	Min.
Lower Teakettle Mountain Zone 1	Columbian ground squirrel	10	2403	4366	457
	Deer	17	3933	9400	370
	Deer mouse	22	1768	4243	588
	Flying squirrel	1	1617		
	Grouse	1	1200		
	Hairy woodpecker	2	361	483	238
	House cat	1	1600		
	House mouse	4	707	1421	351
	Meadow vole	1	1072		
	Shorttail weasel	1	1422		
	Sparrow	1	2052		
Columbia Falls Zone 1	Chipmunk	1	1000		
	Columbian ground squirrel	9	1171	3100	363
	Deer	5	2007	3495	1100
	Deer mouse	10	938	3857	21
	Martin	1	465		
	Meadow vole	41	518	1785	37.5
Coram Zone 3	Chipmunk	5	4666	9863	815
	Columbian ground squirrel	16	929	5199	12.4
	Deer	2	2270	3700	840
	Deer mouse	4	1068	1280	854

Table 8 (continued). FLUORIDE CONCENTRATION IN FEMUR BONES OF INDIGENOUS WILD ANIMALS

Sampling zone	Species	No. Specimens	Fluoride, ppm by weight		
			Mean	Max.	Min.
Coram (continued) Zone 3	Grouse	5	1413	4208	538
	Snowshoe hare	3	837	2053	87.5
Lake Five Zone 4	Bushytail woodrat	1	850		
	Chipmunk	11	887	2218	265
	Columbian ground squirrel	12	627	1154	61.4
	Deer mouse	1	1067		
	Red squirrel	3	754	1511	271
	Snowshoe hare	6	830	1500	48.3
Columbia Mountain Zone 5	Chipmunk	5	694	1542	191
Desert Mountain Zone 6	Chipmunk	2	613	911	315
	Golden-mantled ground squirrel				
South Fork Zone 7	Chipmunk	1	331		
Middle Fork Zone 8	Chipmunk	2	299	454	143
	Columbian ground squirrel	6	374	648	227
	Deer	1	1280		
	Golden-namtled ground squirrel	1	256		
	Snowshoe hare	1	1020		

Table 8 (continued). FLUORIDE CONCENTRATION IN FEMUR BONES OF INDIGENOUS WILD ANIMALS

Sampling zone	Species	No. Specimens	Fluoride, ppm by weight		
			Mean	Max.	Min.
North Fork Zone 9	Chipmunk	1	462		
	Columbian ground squirrel	1	222		
	Coyote	1	268		
	Deer	1	168		
	Deer mouse	4	541	688	210
Headquarters Hill Zone 11	Chipmunk	2	702	784	620
	Columbian ground squirrel	9	324	472	88.5
	Deer	1	1720		
	Deer mouse	2	532	640	424
	Snowshoe hare	1	253		
Belton Hills Zone 12	Chipmunk	7	470	859	190
	Columbian ground squirrel	2	343	508	178
Apgar Ridge & MFRS Zone 13	Chipmunk	5	3394	9863	107
	Columbian ground squirrel	10	735	1670	190
	Golden-mantled ground squirrel	2	782	1299	266
	Snowshoe hare	24	1619	3450	579
Apgar Lookout Zone 14	Chipmunk	3	295	367	214
	Columbian ground squirrel	1	480		

Table 8 (continued). FLUORIDE CONCENTRATION IN FEMUR BONES OF INDIGENOUS WILD ANIMALS

Sampling zone	Species	No. Specimens	Fluoride, ppm by weight		
			Mean	Max.	Min.
Apgar Lookout (continued) Zone 14	Deer	2	582	1040	124
	Snowshoe hare	10	582	1200	234
Boehm's Bear Den Zone 15	Chipmunk	1	415		
	Snowshoe hare	1	625		
Lake McDonald Zone 16	Deer	4	1807	2400	1220
	Snowshoe hare	1	382		
Camas Creek Zone 17	Chipmunk	2	164	212	115
	Snowshoe hare	1	382		
Loneman Mountain Zone 19	Chipmunk	1	367		
	Columbian ground squirrel	1	470		
Controls	Chipmunk	16	109	304	50
	Columbian ground squirrel	16	105	146	35
	Deer	31	225	635	86
	Deer mouse	2	107	113	100
	Grouse	7	209	402	110
	Snowshoe hare	3	83	166[a]	35

a) one adult, others juvenile

concentrations in vegetation from the study area to concentrations in vegetation from control areas.

Among all zones in the study area, the highest fluoride concentrations were found in specimens collected in the Teakettle Mountain, Columbia Falls, and Coram zones, those zones nearest to the aluminum reduction plant. This parallels similar findings of high fluoride concentrations in vegetation in these three zones. For these zones, mean fluoride concentrations in femur bones of animal specimens exceeded those in control animals by factors of 10 to 40.

The highest fluoride concentrations in femur bones of animals collected from any zone within Glacier National Park were found in those from the Apgar Ridge and MFRS zone. Bones from animals from this zone yielded mean fluoride concentrations in the range of 7 to 30 times greater than those of control animals. The average fluoride concentration in snowshoe hares from this zone was about 20 times greater than that in controls; the average in chipmunks was 30 times greater than that in controls.

Results of the fluoride analyses demonstrate that the rates of fluoride accumulated can vary considerably among the species. These differences can be attributed to differences in life span, diet, and seasonal activity of each species.

DISCUSSION AND CONCLUSIONS

VEGETATION DATA

Comparison of data obtained from analysis of vegetation collected within the Columbia Falls-Glacier National Park study area with data from samples obtained in control areas demonstrates unequivocally that excessive fluoride concentrations occur in vegetation growing in a large portion of the study area.

Analyses of vegetation indicate that atmospheric fluorides intrude into Glacier National Park as far as Logan Creek on Logan Pass along the Going-to-the-Sun Highway. Logan Creek is 22 miles inside the Park's southwest boundaries and approximately 28 miles from the aluminum reduction plant, the only major source of atmospheric fluoride emissions in the study area.

During the study period it was noted that fluoride concentrations in coniferous vegetation varied substantially when collections were made at different elevations in a given zone. It was also noted that fluoride concentrations in some coniferous vegetation collected within 2 miles of the aluminum reduction plant were lower than those in conifer samples collected 20 miles from the plant.

Meteorologic measurements made in the study area confirmed that the prevailing daytime winds are from west-southwest (across the Flathead Valley, toward Teakettle Mountain and Badrock Canyon) and, therefore, carry the fluoride emissions of the aluminum plant over Teakettle Mountain toward Glacier National Park. The prevailing nighttime winds are primarily northeast out of Glacier National Park and the North Fork of the Flathead River. They flow over Teakettle Mountain or through Badrock Canyon, carrying the fluoride emissions to the town of Columbia Falls and into the Flathead Valley.

As a result of these two distinct wind patterns -- especially the daytime wind pattern, which occurs when vegetation in the area is carrying on more active metabolism -- variation occurs in the fluoride accumulations in vegetation from the different zones.

The highest fluoride concentrations in coniferous vegetation collected in two of the three most affected zones in the Park (Headquarters Hill and Belton Hills) came from vegetation obtained at an elevation of 3800 to 4400 feet msl. The valley floor in Glacier National Park at Park headquarters is 3100 feet msl. This phenomenon of higher fluoride concentrations in vegetation growing 700 to 1100 feet off the valley floor did not occur in the four zones that make up the southern boundaries of the study area. Instead, in the Columbia Mountain, Doris Mountain, Desert

Mountain, and South Fork zones the highest fluoride concentrations occurred at the lower elevations and decreased at higher elevations.

In some zones, such as Columbia Falls, Lake Five, and Lake McDonald, no such relationship could be established among fluoride accumulations in the vegetation growing at different elevations. The reasons could be slight variation in elevation within these zones or slight differences in fluoride concentrations in the samples from these zones.

Data on fluoride accumulation in coniferous foliage suggest the route taken by fluoride emissions from the aluminum reduction plant. With prevailing daytime southwesterly wind, fluoride emissions from the plant are deflected by the Apgar Mountains and Belton Hills and then are funneled into the Headquarters Hill and Lake McDonald zones of Glacier National Park. Analysis of coniferous samples collected on the highest ridges of the Apgar Mountains and Belton Hills shows that atmospheric fluorides are not being pushed over these high ridges by the prevailing southwesterly daytime winds. The highest fluoride concentrations in coniferous trees in these mountains usually occurred at elevations between 3800 and 4400 feet msl, that is, 700 to 1300 feet above the major Park highway in the Headquarters Hill and Lake McDonald area and approximately 1000 to 2000 feet below the Apgar Mountains and Belton Hills ridge tops. Therefore, it is concluded that these mountains act as a funnel for the fluoride pollution coming from the Columbia

Falls area. This explains why fluoride concentrations found in samples from coniferous trees in the Logan Creek area of the Lake McDonald sampling zone were higher than in those from the top of the Belton Hills and Apgar Mountains.

Data obtained in this study on fluoride in vegetation lead to several general observations. In coniferous vegetation the highest fluoride concentrations are found in the oldest needles, i.e., in the 1968 foliar growth being retained on the trees in 1970; the average fluoride concentrations found in 1969 needles from each zone were approximately half of those found in the 1968 needles, and approximately twice those found in the 1970 needles. When samples from lodgepole, Ponderosa, and white pines are collected in the same zone, analysis shows two trends: (1) lodgepole pine foliage usually has accumulated higher fluoride concentrations than the other two species; and (2) Ponderosa pine foliage has accumulated more than that of the white pine. Although the data show some exceptions to these rankings of pine species according to fluoride accumulation, these exceptions are believed to be attributable to differences in elevation at which the samples were obtained. It further appears that when one species of conifer growing in a given zone has accumulated high fluoride concentrations, the other conifer species will have also.

With specific regard to the study area, comparison of the 1968 foliage of lodgepole, Ponderosa, and white pines with that of the same species in control areas, demonstrates that:

1. In 14 of the 19 zones lodgepole pine foliage had elevated fluoride concentrations;
2. In 12 of the 19 zones Ponderosa pine foliage had elevated fluoride concentrations; and
3. In 11 of the 19 zones white pine had elevated concentrations of fluoride.

A mean fluoride concentration 4 times greater than the mean concentration in samples from control areas is considered to be elevated.

One or more species yielded elevated mean fluoride concentrations in all zones 1 through 16. Thus, in the entire study area of 410 square miles, zones comprising about 375 square miles contained coniferous vegetation that had accumulated elevated fluoride concentrations.

It should also be noted that samples of conifers growing on the remaining 35 square miles of the study area did not yield samples having elevated fluoride concentrations. Much of this area is geographically closer to the major source of fluoride emissions than are areas in Glacier National Park where vegetation had accumulated elevated levels of fluoride. This phenomenon is attributed to topography and wind patterns.

Four major points concerning fluoride accumulation in vegetation in the study area are discussed here because of their long-term ecological consequences. First, excessive fluoride concentrations found in vegetation samples are not attributable to fluoride particulate but to gaseous fluorides. Second, the air monitoring conducted by EPA in the study area in 1970 usually yielded concentrations below the Montana State standard of 1 part fluoride per billion parts of air. Third, after atmospheric fluorides enter the foliage of conifer and broadleaf species, a portion of the fluoride is translocated to the active stem tissues of both hardwoods and conifers, and also to the pollen of conifer cones. Fourth, and last, the fluoride accumulation in the foliage, stems, and reproductive tissues of conifer and broadleaf species is available for ingestion by the indigenous wild animals which utilize any part of these tissues in their normal diets.

With regard to the first point, the data obtained from unwashed and washed coniferous and hardwood stems and terminal buds, collected from the most affected zones within Glacier National Park and control areas, demonstrate that ordinarily less than 1 ppm of fluoride in these tissues can be attributed to fluoride particulate. This is further substantiated by the results of histological studies of needle necrosis in 1969 coniferous foliage from zones within Glacier National Park. In general, necrotic needles contained less than 18 ppm of fluoride and some had less than 12 ppm. All past literature and our own studies around aluminum plants indicate that when concentrations of 12 to 18 ppm are found on and in needles, if any significant portion of the fluoride is in the form of particulate, then necrosis does not occur in 12- to 14- month-old needles.

This conclusion is also substantiated by data from conifer collections made in the Columbia Falls and West Face of Teakettle Mountain zones during the early summer of 1970. Here the 1970 conifer foliage showed concentrations of 20 to 30 ppm of fluoride 1-1/2 months after emerging from the terminal bud, but most of the foliage had not become necrotic at the time of these early collections. Comparison of data from unwashed and washed samples showed that more than half of the fluoride had been removed by washing.

This discussion is not intended to imply that the actual and potential effects of fluoride particulate on the ecology of the zones in the study area are unimportant. It is intended to point out that the excessive fluoride accumulation in the foliage in the southwestern portion of Glacier National Park comes from gaseous fluoride, which will not be reduced in the future by installation of pollution abatement equipment designed to remove only the fluoride particulate.

The second major point to be discussed concerns the results of the 1970 air monitoring in and around Glacier National Park. Although some static fluoride samplers were located in the previously mentioned "hot belts" of fluoride accumulation (3900 to 4400 feet elevation msl), most of the monitoring devices were located at an elevation of about 3100 feet msl. Regardless of whether the samplers were located in the hot belts or lower, the results indicate that the Montana state standard for atmospheric fluorides (1 ppb) was seldom exceeded in Glacier National Park during the 1970 study period.

When the Montana State Board of Health set the standard of 1 ppb for fluorides in the ambient air, it was known that certain species of pine would manifest needle necrosis at a concentration of 1 ppb for 200 hours (Solberg and Adams, 1956). Fluoride resulting from exposure to hydrogen fluoride is a cumulative substance in plant tissues. When it is present in the ambient air at concentrations ranging from even one-tenth to one-fortieth of the state standard of 1 ppb, it has the potential to be detrimental to the health of certain plant species.

The third major point relates to the previously unreported phenomenon of fluoride translocation from the leaf to other plant tissues. Even though further investigations are needed to determine exactly which of the active stem tissues the fluorides are translocated to, and in what form they are stored, several points can be cited now as a result of these studies.

It has been known for some time that fluorides taken in from the ambient air by the leaves or needles of plants are not equally distributed throughout the foliar tissues but migrate and accumulate in greater concentrations in the outer edges of the leaves or, in the case of conifer needles, in the apical or terminal portions of the needles. Thus, the first tissues to succumb to excessive fluoride accumulation are the outermost tissues of the leaves and needles.

The data on fluoride accumulation in the tissues of conifer stems and pollen indicate that the fluorides are concentrating at much higher levels in the pollen tissues than in the stem tissues. Although the ecological and physiological import of this discovery is not known at this time, the knowledge that fluoride can inhibit several metabolic processes that normally occur in these reproductive tissues should encourage investigators to study this potentially serious problem.

The fact that fluoride is translocated from the needles of conifers to the active tissues of stems and terminal buds may explain the abnormal and excessive stem growth of conifers reported by Treshow in his study of fluoride pollution in and around a phosphate plant in Idaho. Since excessive fluorides are known to cause hypertrophy or cell enlargement of thin-walled cells in conifer needles, there is a strong possibility that excessive fluoride concentrations found in conifer stems collected from the Columbia Falls-Glacier National Park study area could also cause cell enlargement or hypertrophy of the thin-walled cells of the young, developing stems.

Effects of the translocation of fluoride from the recipient needles and leaves to the stems and apical meristems should be the subject of further research, since the results of this study and that of the Forest Service (Carlson and Dewey, 1971) show clearly that atmospheric fluorides taken in by plants do not remain solely in the leaf and needle tissues.

The fourth and last point relates to the ingestion by animals of vegetation containing fluorides. In collections of vegetation from zones within Glacier National Park, most of the samples that were of the current year's growth (i.e., leaves of broadleaf species, 1970 conifer needles, and grass samples) yielded fluoride concentrations substantially lower than those found in samples from the Columbia Falls and West Face of Teakettle Mountain zones. Yet the fluoride concentrations in animals collected from the Park's southwest zones were a third to a half of those found in animals from the zones surrounding the aluminum plant.

Many of the animal species utilized in this study do not hibernate and therefore feed on the stems of herbaceous shrubs and on coniferous browse during the winter months. Winter and spring months are wet; so most of the fluoride particulate is probably washed off the vegetation during this time. Thus, wild animals feeding in the Coram zone, the West Face of Teakettle Mountain zone, and the southwest zones of Glacier Park are all feeding on a diet of vegetation which, in winter and spring months, accumulates similar concentrations of fluoride.

This explanation is somewhat substantiated by review of data on fluoride concentrations found in washed stems and terminal buds of vegetation collected from all the different zones of the study area. Results of analysis of plant tissues other than conifer needles also indicate that the indigenous wild animals in the southwest zones of Glacier National Park have little access to any type of vegetation that does not contain excessive fluorides.

ANIMAL DATA

The main objective in the animal portion of the study was to ascertain whether excessive concentrations of fluoride were accumulating in the animals living in the study area.

Early in the study collections of animals from the southwest zones of Glacier National Park confirmed conclusively that excessive fluoride concentrations were indeed accumulating in the animals. To what degree this problem affects the various animal species, and how extensive an area of the Park is affected could not be fully determined.

Most of the animals taken in Glacier National Park were not collected where vegetation had accumulated the highest fluoride concentrations -- that is, at elevations of 3800 to 4400 feet msl in the Apgar Ridge and MFRS, Headquarters Hill and Belton Hills zones. Instead, the animals were taken primarily at the lower elevations between 3100 and 3500 feet. Therefore, data on excessive fluoride concentrations in the animals collected do not reflect the upper limits that could be found in animals in Glacier National Park.

In conclusion, it is reiterated that there are excessive fluoride concentrations in the flora and fauna collected in sampling zones nearby the aluminum reduction plant and in the southwest zones of Glacier National Park. A comparison of fluoride concentrations found in vegetation and in animal species confirms that an increase of several orders of magnitude is occurring in the food chain. The apparent tendancy toward concentration of fluorides in the food chain, as evidenced by results of these studies, suggests that excessive fluoride accumulation in the carnivores of the study area is a strong possibility.

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APPENDIX A

FLUORIDE CONTENT OF CONIFER FOLIAGE

SPECIES ABBREVIATIONS USED IN THE APPENDICES

P.c. = Pinus contorta (lodgepole)

P.m. = Pinus monticola (white)

P.p. = Pinus ponderosa

Ps.m. = Pseudotsuga menziesii (Douglas fir)

P.f. = Pinus flexilis (white)

P.a. = Pinus albicaulis

P.sp. = Picea sp.

P.s. = Pinus sylvestrus

TEAKETTLE MT. ZONE 1

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
71	P.m.	5900	145.0	89.0	9.8
75	P.m.	5000	225.0	125.0	26.0
76	P.m.	5000	188.0	86.0	12.0
79	P.m.	4800	80.0	41.0	12.0
81	P.m.	4850	37.0	23.0	7.4
87	P.m.	4000	225.0	89.0	18.0
88	P.m.	3800	83.0	75.0	18.0
72	P.c.	5700	375.0	182.0	17.0
75	P.c.	5000	582.0	272.0	31.0
76	P.c.	5000	205.0	78.0	7.2
77	P.c.	4950	117.0	43.0	8.0
80	P.c.	4900	143.0	47.0	6.4
82	P.c.	4600	33.0	13.5	4.0
83	P.c.	3900	61.0	20.5	3.9
84	P.c.	4800	240.0	117.0	10.8
85	P.c.	4500	505.0	205.8	20.5
86	P.c.	4400	520.0	260.0	19.5
89	P.c.	3800	165.0	86.0	10.5
296	P.c.	5000	668.0	345.0	61.8
298	P.c.	5700	420.0	234.0	52.0
73	P.p.	5500	410.0	292.0	43.0

TEAKETTLE MT. ZONE 1 (continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
74	P.p.	4900	196.0	80.0	21.5
78	P.p.	4600	133.0	31.0	4.5
80	P.p.	4900	105.0	52.0	8.3
297	P.p.	4900	-	125.8	33.8

COLUMBIA FALLS ZONE 2

GP No.	Species	Fluoride, ppm 1968	1969	1970
ALS-14-1	P.c.	48.6	29.6	17.8
ALS-1-2	P.c.	84.0	38.8	16.0
ALS-5-3	P.c.	100.0	54.0	15.0
ALS-6-4	P.c.	116.0	25.6	11.8
ALS-17-5	P.c.	79.8	50.0	31.0
ALS-18-6	P.c.	30.6	19.2	10.8
ALS-19	P.c.	none	36.6	16.2
Total		458.2	253.8	118.6
Average		76.3	36.1	17.0
ALS-DO-1	P.p.	25.0	11.5	5.0
ALS-15	P.p.	158.0	73.0	43.0
ALS-16	P.p.	128.4	63.0	32.4
ALS-18	P.p.	41.6	15.8	11.6
ALS-19	P.p.	106.0	57.6	23.6
ALS-20	P.p.	18.2	14.2	9.4
ALS-21	P.p.	76.0	43.4	20.4
ALS-22	P.p.	105.0	63.6	37.0
ALS-1	P.p.	114.0	74.0	29.0
ALS-2	P.p.	108.0	83.0	28.6
ALS-3	P.p.	104.0	45.2	17.6
ALS-4	P.p.	88.0	36.4	21.2
ALS-5	P.p.	116	36.0	13.4
ALS-6	P.p.	80.6	35.0	15.0

COLUMBIA FALLS ZONE 2 (Continued)

GP No.	Species	Fluoride, ppm		
		1968	1969	1970
ALS-7	P.p	192.0	96.0	35.0
ALS-23	P.p	38.4	27.6	20.8
ALS-KR-1	P.p	100.0	37.6	23.0
ALS-KR-2	P.p	104	69.0	11.6
ALS-BD-1	P.p	106.0	55.0	52.4
ALS-BD-2	P.p	116.0	38.0	28.0
ALS-ST-1	P.p	92.0	66.8	29.6
ALS-9	P.p	106.0	69.0	32.0
ALS-11	P.p	152	75.0	27.6
ALS-12-1	P.p	110	58.0	28.4
ALS-12-2	P.p	147.6	66.0	24.0
ALS-13-1	P.p	47.0	30.0	16.4
ALS-13-2	P.p	102.0	60.0	24.8
ALS-14-28	P.p	36.4	18.6	11.4
Total		2718.2	1418.3	672.2
Average		96.7	50.6	24.0
ALS-DO-2	Ps.m	43.5	28.2	18.2
ALS-1	Ps.m	150.0	68.4	30.0
ALS-2	Ps.m	150.0	94.0	39.6
ALS-3	Ps.m	164.0	76.0	38.4
ALS-5	Ps.m	81.6	48.6	27.4
ALS-6	Ps.m	80.0	67.0	33.6
ALS-7	Ps.m	150.0	98.0	41.0

COLUMBIA FALLS ZONE 2 (Continued)

GP No.	Species	Fluoride, ppm		
		1968	1969	1970
ALS-9	Ps.m.	132.0	62.0	36.6
ALS-10	Ps.m.	156.0	86.0	24.6
ALS-11	Ps.m.	112.0	65.0	36.4
ALS-12	Ps.m.	182.0	110.0	64.0
ALS-13	Ps.m.	132.0	82.0	56.0
ALS-14	Ps.m.	42.0	37.0	28.4
ALS-15	Ps.m.	145.0	76.8	54.0
ALS-16	Ps.m.	67.0	45.4	32.0
ALS-17	Ps.m.	116.0	90.0	78.0
ALS-19	P-.m.	140.0	59.0	42.8
ALS-20	Ps.m.	32.8	33.0	20.4
ALS-21	Ps.m.	93.0	38.0	30.6
ALS-22	Ps.m.	142.0	77.0	55.4
ALS-23	Ps.m.	39.0	24.8	39.0
ALS-KR-3	Ps.m.	162.0	82.0	29.0

CORAM ZONE 3

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
13	P.c.	3200	29.0	14.0	5.6
14	P.c.	3122	25.0	16.7	5.0
15	P.c.	3250	54.0	29.0	5.8
16	P.c.	3280	67.0	26.0	14.0
39	P.c.	3250	46.0	18.0	12.0
41	P.c.	3500	90.0	82.0	8.4
44	P.c.	3200	64.0	33.0	5.6
45	P.c.	3400	60.0	34.0	5.4
46	P.c.	3600	110.0	67.0	4.9
52	P.c.	3185	52	19.5	4.5
82	P.c.	4600	33.0	13.5	4.0
83	P.c.	3900	61.0	20.5	3.9
84	P.c.	4800	240.0	117.0	9.8
85	P.c.	4500	505.0	205.0	20.5
86	P.c.	4400	520.0	260.0	19.5
89	P.c.	3500	165.0	86.0	10.5
111a	P.c.	3160	24.0	16.0	4.8
111b	P.c.	3160	44.0	24.0	3.7
217	P.c.	3200	26.0	19.0	7.2
218	P.c.	3122	31.0	14.0	5.2
219	P.c.	3250	46.0	29.0	5.6
220	P.c.	3280	47.0	22.5	6.1
242	P.c.	3500	77.0	50.0	9.2

CORAM ZONE 3 (Continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
245	P.c.	3200	87.0	95.0	7.5
247	P.c.	3600	100.0	74.0	8.8
250	P.c.	3300	33.0	17.0	4.5
270	P.c.	3250	34.9	18.5	6.9
271	P.c.	3185	52.0	22.0	7.3
273a	P.c.	3160	27.0	16.6	8.1
273b	P.c.	3160	40.2	24.0	8.2
299	P.c.	3100	34.0	15.2	4.7
300	P.c.	3100	54.0	20.8	5.5
39	P.m.	3250	37.0	29.0	7.3
40	P.m.	3200	44.0	35.0	13.0
42	P.m.	3550	80.0	90.0	23.0
45	P.m.	3400	60.0	50.0	6.2
46	P.m.	3600	51.0	33.0	3.9
81	P.m.	4850	37.0	23.0	7.4
87	P.m.	4000	225.0	89.0	18.0
88	P.m.	3800	83.0	75.0	18.0
136	P.m.	3110	24.0	17.0	4.0
241	P.m.	3200	41.0	28.0	5.8
243	P.m.	3550	93.0	45.0	10.0
246	P.m.	3400	70.0	36.0	8.1
247	P.m.	3600	62.0	41.0	13.5
270	P.m.	3250	34.5	19.8	6.8

CORAM ZONE 3 (Continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
272	P.m.	3110	20.0	17.0	7.7
299	P.m.	3160	12.8	14.9	7.3
43	P.p.	3580	75.0	41.0	2.7
47a	P.p.	3250	40.0	18.0	3.2
47b	P.p.	3250	18.0	16.5	3.7
47c	P.p.	3250	52.0	18.5	13.5
47d	P.p.	3250	37.0	28.0	2.6
219	P.p.	3250	48.0	20.0	3.2
244	P.p.	3580	120.0	27.0	9.5
248b	P.p.	3250	-	11.5	3.7
248c	P.p.	3250	57.0	28.5	2.7
248d	P.p.	3250	36.0	10.0	3.4
250a	P.p.	3300	26.0	12.0	3.8
250b	P.p.	3300	16.0	15.0	7.5
301	P.p.	3150	39.0	12.0	4.1
44	Ps.m.	3200	54.0	29.0	3.5
245	Ps.m.	3200	93.0	49.0	

LAKE FIVE ZONE 4

GP No.	Species	Elevation, feet	Fluoride, ppm 1968	1969	1970
26	P.c.	3200	24.0	10.0	4.6
37	P.c.	3250	28.0	14.0	3.8
38	P.c.	3200	21.0	10.0	5.6
119	P.c.	3300	31.5	15.5	4.4
169	P.c.	3215	19.0	7.0	3.1
225	P.c.	3200	21.0	10.0	4.2
234	P.c.	3200	23.0	8.1	4.8
235	P.c.	3250	27.0	16.0	5.5
264	P.c.	4360	35.0	15.0	8.2
265	P.c.	4280	35.0	17.0	5.6
266	P.c.	4090	22.0	-	7.0
267	P.c.	3950	20.0	17.0	6.4
268	P.c.	3750	26.5	11.5	4.3
269	P.c.	3480	23.0	10.5	3.8
302	P.c.	3180	38.0	21.8	5.5
37	P.p.	3250	24.0	13.0	5.8
38	P.p.	3200	19.0	13.0	4.6
119a	P.p.	3300	22.5	10.0	2.7
119b	P.p.	3300	14.0	12.0	3.6
170	P.p.	3250	18.0	10.0	2.3
234	P.p.	3200	21.5	9.9	3.2
235	P.p.	3250	26.0	15.0	5.5
263	P.p.	4280	20.0	16.5	4.4
262	Ps.m.	4090	23.0	17.0	7.3

COLUMBIA MOUNTAIN ZONE 5

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
190	P.f.	7234	4.5	4.4	2.8
191	P.f.	7160	3.5	3.4	2.4
192	P.f.	6650	4.2	4.4	3.1
193	P.f.	6520	5.4	4.3	3.1
195	P.f.	6150	5.9	5.2	1.5
197	P.f.	5790	7.1	7.3	4.6
198	P.f.	5400	14.5	7.0	7.0
202	P.f.	7100	4.6	3.5	2.6
203	P.f.	7210	3.9	3.7	3.1
192	P.c.	6650	3.4	2.7	2.0
194	P.c.	6220	5.2	4.7	2.5
195	P.c.	6150	14.2	5.5	3.7
197	P.c.	5790	6.7	3.3	2.1
198	P.c.	5400	13.7	5.0	3.3
196	P.p.	6050	7.9	7.6	4.5
197	P.p.	5790	8.3	9.7	6.2
198	P.p.	5400	12.6	7.8	7.0
199	P.p.	4920	63.0	26.5	7.3
200	P.p.	4530	79.0	38.5	18.5
201	P.p.	4030	72.0	38.0	11.6
198	Ps.m.	5400	14.0	8.3	6.3

DESERT MOUNTAIN ZONE 6

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
113	P.p.	3300	22.5	10.5	3.8
122	P.p.	4400	17.0	5.2	2.0
123a	P.p.	3900	12.0	5.6	2.0
123b	P.p.	3900	7.4	3.7	1.9
171	P.p.	4020	24.0	11.7	4.7
172	P.p.	5500	10.0	3.5	2.3
182	P.p.	5800	15.5	9.2	3.9
183	P.p.	5700	11.5	5.6	3.4
184	P.p.	5500	12.5	7.3	4.0
187	P.p.	4300	30.5	13.0	7.0
188	P.p.	4150	27.0	12.5	3.0
284	P.p.	4020	22.5	12.6	3.9
285	P.p.	5500	17.7	7.3	5.2
122	P.c.	4400	31.5	11.0	2.2
172	P.c.	5500	17.5	5.2	2.3
175	P.c.	6400	6.5	2.7	1.5
180	P.c.	6180	7.2	5.4	7.5
181	P.c.	5930	12.2	8.1	7.6
184	P.c.	5500	17.0	4.4	5.3
186	P.c.	4600	20.5	8.2	2.7
187	P.c.	4300	34.0	18.0	4.2
285	P.c.	5500	12.4	7.0	3.6

DESERT MOUNTAIN ZONE 6 (Continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
122	P.m.	4400	21.0	10.0	3.2
173	P.m.	5200	14.0	6.0	1.8
286	P.m.	5200	10.4	6.8	4.3
174	P.f.	6350	10.0	6.4	3.5
175	P.f.	6400	4.3	4.0	2.7
181	P.f.	5930	5.2	4.6	3.4
184	P.f.	5500	9.9	12.0	5.0
185	P.f.	5180	13.3	10.4	5.5

SOUTH FORK ZONE 7

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
112	P.c.	3200	14.5	6.8	1.9
115	P.c.	3580	6.4	3.8	1.6
250	P.c.	3300	33.0	17.0	4.5
112	P.m.	3200	15.0	8.5	5.2
114	P.m.	3430	11.0	6.0	6.3
115	P.m.	3580	6.7	6.3	4.4
117	P.m.	3600	4.3	2.7	2.0
118	P.m.	3670	3.6	2.4	1.6
121a	P.m.	3300	12.8	8.2	2.8
121b	P.m.	3300	14.0	9.1	2.6
113	P.p.	3300	22.5	10.5	3.8
116a	P.p.	3600	3.9	4.3	3.0
116b	P.p.	3600	7.4	2.9	3.7
119a	P.p.	3300	22.5	10.8	2.7
119b	P.p.	3300	14.0	12.0	3.6
250a	P.p.	3300	26.0	12.0	3.8
250b	P.p.	3300	16.0	15.0	7.5

MIDDLE FORK ZONE 8

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
22	P.c.	3550	8.4	8.6	5.2
23	P.c.	3660	23.0	7.2	3.5
24	P.c.	3600	29.5	10.0	4.6
25	P.c.	3450	26.5	11.0	3.9
62	P.c.	3350	5.2	4.2	4.2
63	P.c.	3370	10.0	5.0	3.4
64	P.c.	3370	7.0	5.7	3.5
66	P.c.	3700	5.6	4.1	3.5
67	P.c.	3750	3.2	3.2	2.5
224	P.c.	3600	16.5	8.3	3.7
65	P.m.	3400	5.2	3.7	3.5
67	P.m.	3750	3.5	3.0	1.7
68	P.m.	4500	4.3	3.5	2.4

NORTH FORK ZONE 9

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
7	P.c.	3400	8.5	3.3	4.4
8	P.c.	3380	8.4	6.6	3.3
9	P.c.	3400	14.0	9.7	4.4
10	P.c.	3400	10.0	4.5	4.7
12	P.c.	3200	20.5	6.4	3.6
35	P.c.	3400	15.0	7.2	4.4
36	P.c.	3300	8.4	5.8	5.2
53	P.c.	3122	9.2	3.8	7.2
215	P.c.	3400	4.8	4.2	2.8
216	P.c.	3200	7.4	4.2	2.4
233	P.c.	3400	15.0	7.2	3.1
7	P.m.	3400	14.0	5.3	3.1
8	P.m.	3380	5.6	4.3	3.7
9	P.m.	3400	11.0	7.2	7.4
11	P.m.	3100	13.0	6.5	4.6
12	P.m.	3200	14.0	7.8	4.4
35	P.m.	3400	12.0	7.2	4.6
36	P.m.	3300	9.2	7.0	5.2
214	P.m.	3500	5.7	4.3	3.9
216	P.m.	3200	6.4	4.3	5.7
233	P.m.	3400	11.5	9.0	9.0
10	P.p.	3400	8.0	5.8	4.0
36	P.p.	3300	11.0	7.0	3.7

DORIS MOUNTAIN ZONE 10

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
204	P.c.	5860	4.3	2.2	1.5
205	P.c.	6620	6.2	2.5	2.6
206	P.c.	6330	3.2	3.4	7.8
207	P.c.	6000	4.2	2.5	2.0
202	P.f.	7100	4.6	3.5	2.6
203	P.f.	7210	3.9	3.7	3.1
204	P.f.	6850	3.9	2.6	2.1
206a	P.f.	6330	4.9	4.0	4.2
206b	P.f.	6330	4.0	4.1	2.2
207	P.f.	6000	5.5	3.6	2.0
205	P.p.	6620	3.5	2.8	1.7
206	P.p.	6330	5.5	2.5	4.0
207	P.p.	6000	3.7	4.5	3.0
208	P.p.	5500	4.3	3.0	2.7
209	P.p.	5300	6.6	6.4	5.5
210	P.p.	5000	8.6	5.6	6.7
211	P.p.	4500	44.5	14.5	3.3
212	P.p.	4080	15.2	9.1	2.9

HEADQUARTERS HILL, ZONE 11

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
69	P.c.	3190	29.0	16.0	5.2
90	P.c.	3330	20.5	7.0	3.6
93	P.c.	3850	24.0	12.8	3.7
94	P.c.	3950	34.0	12.8	2.5
95	P.c.	4100	29.0	13.5	3.25
96	P.c.	4250	23.5	11.5	9.8
97	P.c.	4600	42.0	17.5	3.7
99	P.c.	4800	37.0	13.5	4.4
100	P.c.	4900	33.0	12.2	2.3
221	P.c.	3400	27.5	13.0	5.2
287	P.c.	4800	35.0	16.0	7.7
289	P.c.	4250	23.8	21.3	7.3
290	P.c.	4600	41.7	18.2	7.1
69	P.m.	3190	19.0	12.0	6.4
92	P.m.	3820	22.0	13.5	4.6
93	P.m.	3850	27.5	8.2	3.0
95	P.m.	4100	31.0	29.0	4.3
249	P.m.	3190	14.0	6.9	5.2
90	P.p.	3330	21.8	16.0	8.7
91	P.p.	3480	30.0	17.4	3.2
95	P.p.	4100	20.5	26.0	3.4
96	P.p.	4250	23.0	13.0	2.0
98	P.p.	4700	28.0	13.5	2.7

HEADQUARTERS HILL ZONE 11 (Continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
101	P.p.	4300	32.0	14.5	2.4
102	P.p.	3800	32.0	19.0	3.6
288	P.p.	4300	40.0	21.0	6.1
289	P.p.	4250	25.4	18.0	5.1
291	P.p.	4700	36.5	19.0	5.7
101	Ps.m.	4300	48.0	19.0	4.0
288	Ps.m.	4300	54.0	24.4	12.0

BELTON HILLS ZONE 12

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
149	P.c.	5980	31.0	14.0	6.3
150	P.c.	5608	22.0	7.4	3.6
151	P.c.	5580	6.3	6.4	2.9
153	P.c.	5340	23.5	7.3	2.8
154	P.c.	5080	21.0	7.0	1.9
156	P.c.	4450	31.5	15.0	4.3
157	P.c.	4200	36.0	17.5	5.3
251	P.c.	3580	28.5	11.8	5.2
252	P.c.	3800	33.0	14.5	5.3
253	P.c.	4160	35.0	15.3	6.3
254	P.c.	4480	21.5	12.0	4.5
255	P.c.	4500	37.5	12.0	5.7
256	P.c.	4400	35.0	17.0	6.0
257	P.c.	4200	38.5	17.2	6.7
260	P.c.	3800	40.0	15.5	4.8
149	P.f.	5980	16.0	11.5	8.6
151	P.f.	5580	17.0	11.0	5.8
152	P.f.	5650	8.3	5.0	1.5
151	P.m.	5580	22.0	12.5	5.1
155	P.m.	4820	15.0	7.4	4.9
158	P.p.	4200	16.0	10.4	3.1
251	P.p.	3580	39.0	19.0	6.7
258	P.p.	4000	33.8	15.3	4.4
259	P.p.	3910	31.0	17.5	4.8
261	P.p.	3600	26.0	11.0	3.4

APGAR RIDGE AND MERS ZONE 13

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
28	P.c.	3450	26.0	9.8	4.8
29	P.c.	3200	20.0	6.8	5.0
34	P.c.	3200	45.0	22.0	6.5
148	P.c.	3200	52.0	20.0	2.3
160	P.c.	4920	20.0	6.8	4.0
161	P.c.	4750	34.0	7.8	5.1
162	P.c.	4460	13.0	5.8	2.8
163	P.c.	4380	20.0	7.5	2.3
164	P.c.	4300	10.0	3.3	3.0
165	P.c.	4190	26.0	10.5	2.8
166	P.c.	3900	43.5	19.5	6.0
178	P.c.	-	59.0	23.0	7.2
230	P.c.	3200	41.0	18.0	5.0
279	P.c.	4190	24.0	12.5	7.7
29	P.m.	3200	21.0	13.0	2.3
54	P.m.	3200	15.0	9.0	6.6
160	P.m.	4920	23.0	9.0	6.2
161	P.m.	4750	12.0	7.8	5.7
162	P.m.	4460	16.5	6.0	4.3
276	P.m.	3200	9.1	6.4	8.0
30	P.p.	3200	23.0	10.0	6.4
50a	P.p.	3200	25.0	10.0	2.5
50b	P.p.	3200	24.0	18.1	2.5

APGAR RIDGE ZONE AND MFRS ZONE 13 (Continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
165a	P.p.	4190	15.0	8.6	2.8
165b	P.p.	4190	21.0	10.2	3.8
165c	P.p.	4190	26.0	14.0	3.8
166	P.p.	3900	51.0	27.0	7.5
167a	P.p.	3700	28.0	11.0	3.5
229	P.p.	3200	-	8.8	2.5
278	P.p.	3200	26.0	12.0	4.3
279b	P.p.	4190	20.0	7.1	5.3
279c	P.p.	4190	27.0	13.0	5.2
280	P.p.	3900	37.5	20.8	4.4
281	P.p.	3700	23.0	15.2	4.6
159	P.f.	5030	15.5	8.2	7.2

APGAR LOOKOUT ZONE 14

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
1	P.c.	3175	23	7.2	4.8
2	P.c.	3400	11.0	8.5	4.5
27	P.c.	3250	21.0	11.5	3.8
51	P.c.	3150	12.0	9.6	4.1
137	P.c.	5236	22.0	9.0	3.5
138	P.c.	4980	17.0	5.3	2.9
139	P.c.	4620	11.0	5.5	2.5
140	P.c.	4120	24.0	9.7	2.9
141	P.c.	3760	11.0	4.6	1.4
213a	P.c.	3175	24.0	12.5	4.9
226	P.c.	3250	28.0	10.0	1.9
227	P.c.	3450	18.5	7.2	4.1
228	P.c.	3200	21.0	8.9	3.9
293	P.c.	5236	23.0	17.0	15.0
295	P.c.	4980	17.5	9.5	5.3
55	P.p.	3250	21.0	10.0	5.4
140	P.p.	4120	18.0	9.0	2.9
275	P.p.	3250	20.5	9.1	4.9
292	P.p.	3800	36.5	28.9	16.4
294	P.p.	4120	21.7	10.4	3.5
140	P.m.	4120	5.8	4.6	3.3
142	P.m.	3310	12.0	6.3	2.6

BOEHM'S BEAR DEN ZONE 15

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
30a	P.m.	3430	11.0	6.0	5.4
30b	P.m.	3430	4.6	7.4	1.9
32	P.m.	3200	6.2	5.0	3.3
49	P.m.	3400	16.0	4.3	1.8
176	P.m.	-	7.8	6.4	6.2
177	P.m.	-	5.5	5.7	4.9
179	P.m.	-	7.1	7.0	5.0
277a	P.m.	3400	4.3	4.9	3.2
277b	P.m.	3400	5.3	4.8	4.9
31	P.c.	3400	8.3	5.9	3.2
32	P.c.	3200	12.0	2.8	3.3
33	P.c.	3200	26.0	12.0	4.3
34	P.c.	3200	45.0	22.0	6.5
231	P.c.	3200	21.5	10.5	3.6
277	P.p.	3400	6.9	4.5	2.7

LAKE MCDONALD ZONE 16

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
17	P.c.	3400	28.0	14.0	5.4
18	P.c.	3300	19.0	9.8	4.0
19	P.c.	3250	22.0	14.0	4.1
21	P.c.	3150	20.0	4.9	4.4
56	P.c.	3600	5.3	2.9	3.0
107	P.c.	4900	9.2	4.7	2.2
108	P.c.	5010	6.1	3.0	2.9
145	P.c.	4100	10.5	6.9	2.0
222	P.c.	3300	14.5	10.0	2.9
223a	P.c.	3250	8.5	3.8	2.1
223b	P.c.	3250	12.0	5.1	1.8
18	P.m.	3300	24.4	13.5	5.8
20	P.m.	3250	17.5	8.8	4.5
21	P.m.	3150	8.7	7.0	3.6
56a	P.m.	3600	23.0	17.0	8.3
56b	P.m.	3600	22.0	13.0	6.2
57	P.m.	3300	11.0	6.6	5.0
58	P.m.	3400	6.8	6.0	6.0
59	P.m.	4000	13.0	6.8	5.6
60	P.m.	3400	10.5	7.0	5.0
61	P.m.	3350	10.0	6.8	<1.0
103	P.m.	3470	11.3	4.2	4.2
104	P.m.	3800	10.0	6.7	5.3

LAKE MCDONALD ZONE 16 (Continued)

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
105a	P.m.	4250	11.0	5.9	4.3
105b	P.m.	4250	6.1	3.0	2.8
105c	P.m.	4250	11.5	9.3	4.1
106	P.m.	4400	11.0	5.5	3.6
107	P.m.	4900	8.3	5.5	3.9
108	P.m.	5010	6.3	4.7	4.3
109	P.m.	5020	8.0	4.4	3.2
110	P.m.	5000	11.0	5.2	4.1
143	P.m.	4480	5.5	3.8	3.3
144	P.m.	4290	22.0	9.0	3.8
145	P.m.	4100	5.2	3.1	3.1
147a	P.m.	3500	7.0	3.8	1.9
147b	P.m.	3500	2.9	2.8	2.5
222	P.m.	3300	10.8	5.2	4.6
274a	P.m.	3600	18.0	8.0	6.1
274b	P.m.	3600	12.4	11.1	4.8
105	P.f.	4250	9.5	13.0	5.8

CAMAS CREEK ZONE 17

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
2	P.c.	3400	11.0	8.5	3.4
4	P.c.	3800	8.2	5.4	3.6
5	P.c.	3750	9.7	3.9	3.8
6	P.c.	3500	8.0	4.3	3.5
124	P.c.	3550	8.1	3.4	2.3
126	P.c.	3780	4.8	2.9	1.6
3	P.m.	3800	9.3	7.1	4.8
124	P.m.	3550	8.0	6.4	4.2
127	P.m.	3600	2.8	1.4	1.9
125	P.p.	3600	9.1	4.3	2.5

HUCKLEBERRY MOUNTAIN ZONE 18

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
70	P.a.	6100	3.8	1.4	1.9
120	P.a.	5500	5.7	2.4	1.5
168	P.a.	6500	5.6	5.0	2.8
189	P.a.	6400	7.5	8.0	3.2
282	P.a.	4700	7.0	5.7	5.0
283	P.a.	5650	12.5	5.7	6.4

LONEMAN MOUNTAIN ZONE 19

GP No.	Species	Elevation, feet	Fluoride, ppm		
			1968	1969	1970
128	P.f.	6910	8.4	5.4	2.4
129	P.f.	6580	8.5	6.2	1.7
130	P.f.	6100	4.2	5.4	2.7
132	P.f.	5350	4.3	4.7	2.6
129	P.c.	6580	7.0	3.3	2.1
130	P.c.	6100	6.2	4.3	2.6
131	P.c.	5440	3.6	2.9	1.5
133	P.m.	4530	3.2	2.2	3.1
134	P.m.	4380	3.1	3.7	3.4
135a	P.p.	3950	9.6	4.3	1.6
135b	P.p.	3950	7.9	5.4	2.4

CONTROLS - SWIFTCURRENT

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
SWC-5	Lodgepole Pine	2.9	2.3	1.6

CONTROLS - MANY GLACIER

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
MGC-3	Lodgepole Pine	3.7	3.5	2.4
MGC-4	Lodgepole Pine	3.3	2.5	2.2

CONTROLS - SWAN VALLEY, MONTANA

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
JCC-1[1]	Ponderosa Pine	5.0	3.4	2.2
JCC-1[2]	Ponderosa Pine	4.2	3.7	2.7

CONTROLS - TWIN CREEK, MONTANA

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
TWC-1	Ponderosa Pine	2.1	1.9	1.8
TWC-2[1]	Douglar Fir	1.8	4.1	1.5
TWC-2[2]	Douglas Fir	1.7	1.5	1.5

CONTROLS - ST. REGIS, MONTANA

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
STR-1	Ponderosa Pine	2.9	2.7	2.7
STR-4	Ponderosa Pine	1.6	1.6	1.6
STR-11	Ponderosa Pine	1.1	1.3	1.1
STR-13	Ponderosa Pine	2.5	1.2	2.2
STR-19	Ponderosa Pine	1.8	2.1	1.4
STR-3	Lodgepole Pine	2.4	2.3	1.7
STR-7	Lodgepole Pine	1.0	1.0	1.2
STR-9	Lodgepole Pine	1.2	1.2	1.1
STR-14	Lodgepole Pine	1.2	1.5	1.4
STR-17	Lodgepole Pine	1.4	5.2	1.2
STR-20	Lodgepole Pine	1.3	3.9	1.0
STR-5	White Pine	1.5	2.0	2.0
STR-10	White Pine	1.7	1.3	1.1
STR-15	White Pine	1.1	1.1	1.4
STR-18	Douglas Fir	1.9	1.8	1.5

CONTROLS - ROGERS PASS, MONTANA

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
RP-1	Lodgepole Pine	2.1	2.4	2.8
RP-2	Douglas Fir	2.9	3.2	1.8
RP-4	White Pine	3.0	3.0	2.5

CONTROLS - ELK CREEK, MONTANA

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
C-1	Ponderosa Pine	2.4	2.3	2.1
C-2	Lodgepole Pine	2.2	2.1	2.0
C-3	Lodgepole Pine	2.0	1.9	3.2

CONTROLS - UPPER ST. MARY'S LAKE

Collection number	Species	Fluoride, ppm		
		1968	1969	1970
UPC-1	Lodgepole Pine	2.8	2.7	4.5
UPC-2	Lodgepole Pine	3.9	3.3	2.7

APPENDIX B

FLUORIDE CONTENT OF CONIFER POLLEN

POLLEN STUDY

Collection number	Species	Location	Fluoride, ppm
GP-76	P.c.	Teakettle Zone 1	31.0
GP-77	P.c.		32.0
GP-83	P.c.		13.7
GP-84	P.c.		16.0
GP-13	P.c.	Coram Zone 3	8.0
GP-14	P.c.		11.0
GP-44	P.c.		14.0
GP-52	P.c.		9.8
GP-82	P.c.		13.7
GP-83	P.c.		16.0
GP-111	P.c.		13.6
GP-47b	P.p.		9.7
GP-26	P.c.	Lake Five Zone 4	19.8
GP-37	P.c.		11.0
GP-38	P.c.		16.0
GP-192	P.c.	Columbia Mountain Zone 5	5.1
GP-194	P.c.		7.3
GP-181	P.c.	Desert Mountain Zone 6	19.5
GP-23	P.c.	Middle Fork Zone 8	8.0
GP-24	P.c.		7.6
GP-25	P.c.		6.5
GP-62	P.c.		7.7
GP-64	P.c.		4.0

POLLEN STUDY (Continued)

Collection number	Species	Location	Fluoride, ppm
GP-68	P.c.	Middle Fork Zone 8	5.7
GP-65	P.m.		4.0
GP-67	P.m.		1.7
GP-12	P.c.	North Fork Zone 9	6.4
GP-35	P.c.		8.8
GP-36	P.p.		9.2
GP-69	P.c.	Headquarters Hill Zone 11	16.0
GP-96	P.c.		10.0
GP-97	P.c.		18.0
GP-99	P.c.		17.5
GP-100	P.c.		12.0
GP-102	P.p.		12.2
GP-156	P.c.	Belton Hills Zone 12	13.3
GP-27	P.c.	Apgar Ridge Zone 13	17.8
GP-29	P.c.		6.1
GP-34	P.c.		12.0
GP-30a	P.m.	Boehm's Bear Den Zone 15	3.0
GP-31	P.c.		5.4
GP-33	P.c.		8.4
GP-17	P.c.	Lake McDonald Zone 16	9.6
GP-19	P.c.		5.8
GP-59	P.m.		6.0
GP-60	P.m.		10.0

POLLEN STUDY (Continued)

Collection number	Species	Location	Fluoride, ppm
GP-126	P.c.	Camas Creek Zone 17	5.7
GP-124	P.c.		3.8
GP-70	P.f.	Huckleberry Mountain Zone 18	1.9
GP-120	P.f.		6.6

POLLEN STUDY CONTROLS

Collection number	Species	Location	Fluoride, ppm
STR-14		St. Regis	1.72
RP-1		Rogers Pass	3.8
STM-1		St. Mary's Lake	4.5
STM-2		St. Mary's Lake	5.5
MG-3		Many Glacier	3.6
MG-4		Many Glacier	4.5
SWC-5		Swiftcurrent	3.0

APPENDIX C

FLUORIDE CONTENT OF TERMINAL BUDS

WEST COLUMBIA FALLS ZONE 2

Collection number	Species	Fluoride, ppm	Washed or unwashed
ALS-1	Ps.m.	9.8 13.6	Washed Unwashed
ALS-15	P.p.	8.2	Unwashed
ALS-27	P.p.	6.4	Washed
ALS-27	Ps.m.	8.4	Washed
ALS-28	P.p.	3.8	Washed
ALS-28	Ps.m.	7.8	Washed
ALS-29	P.p.	3.6	Washed
ALS-30	P.p.	5.2 5.2	Washed Unwashed
ALS-31	P.p.	5.9 7.2	Washed Unwashed
ALS-32	P.p.	5.4	Washed
ALS-33	P.p.	7.9 6.0	Washed Unwashed
ALS-34	P.p.	3.8	Washed
ALS-35	P.p.	4.6	Washed
ALS-36	P.p.	3.6	Washed
ALS-37	P.p.	4.0	Washed
ALS-38	P.p.	7.0 6.0	Washed Unwashed
ALS-39	Ps.m.	7.24	Washed
ALSJ-1	P.c.	6.1	
ALS-21	P.p.	12.8	
ALS-21	Ps.m.	17.7	

WEST COLUMBIA FALLS ZONE 2 (Continued)

Collection number	Species	Fluoride, ppm	Washed or unwashed
ALS-22	P.p.	12.4	
ALS-22	Ps.m.	34.5	
ALS-23	Ps.m.	14.4	
ALSK-1	P.p.	11.8	
ALSSt-1	P.p.	8.0	
ALS-17	P.c.	8.6	
ALS-18	P.p.	7.8	
ALS-19	P.c.	7.2 12.0	Washed Unwashed
ALS-21	P.p.	10.4	
ALS-22	P.p.	7.0 7.0	Washed Unwashed
ALS-24	Ps.m.	7.9	
ALS-25	P.p.	4.2	Washed
ALS-25	Ps.m.	3.7 5.8	Washed Unwashed
ALS-25	P.sp.	5.8	Washed
ALS-26	P.p.	7.8 7.2	Washed Unwashed

EAST COLUMBIA FALLS ZONE 2

Collection number	Species	Fluoride, ppm	Washed or unwashed
PS-10a	P.p.	8.8 11.4	Unwashed Washed
PS-10d	P.c.	5.2	Washed
PS-10e	P.c.	15.0	Washed
PS-10f	Ps.m.	12.0	
PS-10g	Ps.m.	9.4	
PS-10h	P.c.	8.2	Washed
PS-10i	P.s.	6.6	Washed

SOUTH FORK FLATHEAD ZONE 7

Collection number	Species	Fluoride, ppm	Washed or unwashed
GP-112	P.c.	4.0	Washed
GP-115	P.c.	3.4	Washed
GP-115	P.m.	7.0	

GLACIER PARK ZONES 11, 12, 13

Collection number	Species	Fluoride, ppm	Washed or unwashed
G-5	P.c.	3.68	
GP-7	P.c.	3.8	
GP-8	P.c.	4.4	
G-10[3]	P.p.	2.6	Washed
G-11	P.p.	3.2	Washed
G-16	P.c.	4.8	
G-20	P.p.	2.9	Washed
G-21	P.p.	2.7	

APPENDIX D

FLUORIDE CONTENT OF GRASS

FLUORIDE CONTENT OF GRASS

Sample number	Location	Fluoride, ppm
GPG-74	Teakettle Mountain Zone 1	275.0
GPG-75		42.0
GPG-76		78.0
GPG-77		89.0
GPG-78		24.5
GPG-79		16.2
GPG-60	Coram Zone 3	4.5
GPG-61		7.4
GPG-62		9.4
GPG-63		7.9
GPG-64		7.0
GPG-65		16.0
GPG-66		5.6
GPG-67		7.0
GPG-68		7.6
GPG-69		64.0
GPG-70		23.0
GPG-71		17.0
GPGH-1	Coram (Hay) Zone 3	9.8
GPGH-2		17.0
GPGH-3		14.0
GPGH-4		20.0
GPGH-5		5.8
GPGH-6		11.0

FLUORIDE CONTENT OF GRASS (Continued)

Sample number	Location	Fluoride, ppm
GPG-52	Lake Five Zone 4	2.7
GPG-53		7.4
GPG-54		6.2
GPG-72	Columbia Mountain Zone 5	14.0
GPG-55	Desert Mountain Zone 6	11.0
GPG-56		8.3
GPG-57		2.5
GPG-58		1.8
GPG-59		4.5
GPG-49	South Fork Zone 7	6.5
GPG-50		4.8
GPG-51		10.0
GPG-39	Middle Fork Zone 8	7.3
GPG-40		1.0
GPG-41		1.0
GPG-42		4.2
GPG-43		2.1
GPG-44		4.8
GPG-45		3.8
GPG-46		7.2
GPG-47		4.7
GPG-48		3.7
GPG-32	North Fork Zone 9	9.3

FLUORIDE CONTENT OF GRASS (Continued)

Sample number	Location	Fluoride, ppm
GPG-33	North Fork Zone 9	6.7
GPG-34		2.7
GPG-35		6.7
GPG-36		8.8
GPG-37		4.6
GPG-38		5.6
GPG-73	Doris Mountain Zone 10	3.8
GPG-1	Headquarters Hill Zone 11	4.4
GPG-2		6.2
GPG-3		12.3
GPG-4		8.0
GPG-22	Belton Hills Zone 12	17.5
GPG-23		6.5
GPG-24		6.6
GPG-5	Apgar Ridge and MFRS Zone 13	2.8
GPG-6		8.0
GPG-7		12.5
GPG-12	Apgar Lookout Zone 14	11.0
GPG-13		1.9
GPG-14		1.6
GPG-8	Boehm's Bear Den Zone 15	1.0
GPG-9		2.9
GPG-10		5.3
GPG-11		2.1

FLUORIDE CONTENT OF GRASS (Continued)

Sample number	Location	Fluoride, ppm
GPG-15	Lake McDonald Zone 16	4.0
GPG-16		26.5
GPG-17		11.0
GPG-18		2.7
GPG-19		6.6
GPG-20		13.5
GPG-21		8.8
GPG-27	Camas Creek Zone 17	5.5
GPG-28		5.7
GPG-29		6.2
GPG-30		4.7
GPG-31		3.6
GPG-25	Loneman Lookout Zone 19	3.4
GPG-26		5.8

COLUMBIA FALLS ZONE 2

Collection number	Fluoride, ppm
GPALS-1	66.0
GPALS-2	90.0
GPALS-3	71.6
GPALS-4	68.0
GPALS-5	86.0
GPALS-6	85.6
GPALS-8	140.0
GPALS-9	270.0
GPALS-10	102.0
GPALS-11	110.0
GPALS-12	98.0
GPALS-13	250.0
GPALS-15	240.0
GPALS-16	180.0
GPALS-17	410.0
GPALS-19	232.0
GPALS-21	100.0
GPALS-22	186.0
GPALS-23	48.0

CONTROL GRASS SAMPLE DATA

Sample number	Fluoride, ppm
STR-2	3.8
STR-6	3.4
STR-8	5.2
STR-12	2.75
STR-16	5.7
CV(3)-1	4.1
CV-2	2.65
CV-3	4.0
CV-4	3.85
CV-5	5.1
CV-6	5.2
CV-7	4.3
RP-3	7.6
STM-2	7.8
MG-3	2.0
MG-4	2.6

APPENDIX E

FLUORIDE CONTENT OF ANIMAL BONE TISSUE

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TEAKETTLE MOUNTAIN ZONE 1

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
RB-1	Columbian Ground Squirrel	457.1	68.5
RB-2	Columbian Ground Squirrel	2700.3	4122.3
FB-3	Columbian Ground Squirrel	578.5	779.6
RB-4	Columbian Ground Squirrel	606.0	863.0
RB-5	Columbian Ground Squirrel	949.7	1311.7
RB-6	Columbian Ground Squirrel	2522.2	3472.2
RB-7	Columbian Ground Squirrel	4366.1	5849.0
RB-8	Columbian Ground Squirrel	3312.8	4462.8
RB-9	Columbian Ground Squirrel	2643.1	3625.3
RB-10	Columbian Ground Squirrel	3894.4	5308.2
RB-11	Deer Mouse	1758.6	2428.5
RB-12	Deer Mouse	976.1	1366.6
RB-13	Deer Mouse	3378.3	4629.6
RB-14	Deer Mouse	587.8	808.3
RB-15	Deer Mouse	633.3	791.4
RB-16	Deer Mouse	921.7	1247.0
RB-17	Deer Mouse	1754.0	2321.4
RB-18	House Mouse	506.5	706.0
RB-19	Shorttail Weasel	1421.5	2013.8
RB-20	Deer Mouse	2705.8	3538.4
RB-21	Deer Mouse	2564.2	3419.0
RB-22	Deer Mouse	2045.4	2647.0
RB-23	House Cat	1660.0	2371.4

TEAKETTLE MOUNTAIN ZONE 1 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
RB-24	Hairy Woodpecker	237.9	329.8
RB-25	Hairy Woodpecker	483.3	707.3
RB-26	White Crowned Sparrow	2051.7	3305.5
RB-27	Flying Squirrel	1616.6	2255.8
RB-28	House Mouse	1421.4	1990.0
RB-29	House Mouse	550.0	687.5
RB-30	Deer Mouse	818.1	1125.0
RB-31	Deer Mouse	4243.2	6038.4
RB-32	Deer Mouse	2125.0	3090.9
RB-33	Deer Mouse	3733.3	3733.0
RB-34	Deer Mouse	1125.0	1565.0
RB-35	Deer Mouse	2055.0	2642.8
RB-36	Meadow Vole	1072.0	1180.0
RB-37	House Mouse	351.0	500.0
RB-38	Deer Mouse	1875.0	2678.5
RB-39	Deer Mouse	1392.8	2052.6
RB-40	Deer Mouse	737.1	1121.1
RB-41	Deer Mouse	1157.8	1466.6
RB-42	Deer Mouse	696.8	892.0
RB-43	Deer Mouse	1607.1	2142.8
GPA-211	Ruffled Grouse	1200.0	
1	Mule Deer	5600.0	
2	Mule Deer	4200.0	
3	Mule Deer	9400.0	

TEAKETTLE MOUNTAIN ZONE 1 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
4	Mule Deer	2200.0	
5	Faun Mule Deer	1250.0	
10	Mule Deer	2240.0	
20		7150.0	
23	Whitetail Deer	3450.0	
24		5660.0	
28		1370.0	
29		5700.0	
32		1250.0	
36		2580.0	
GPA-103		370.0	
15		2300.0	
D 1	Whitetail Deer	4785.0	
D 2	Whitetail Deer	7350.0	

COLUMBIA FALLS ZONE 2

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
CFA-121	Meadow Vole	180	240
CFA-122	Meadow Vole	256	341
CFA-123	Meadow Vole	229	305
CFA-124	Meadow Vole	340	453
CFA-125	Meadow Vole	485	646
CFA-126	Meadow Vole	208	277
CFA-127	Meadow Vole	445	593
CFA-128	Meadow Vole	360	480
CFA-129	Meadow Vole	133	177
CFA-130	Meadow Vole	93.5	124.5
CFA-131	Meadow Vole	37.5	50.0
CFA-132	Meadow Vole	91.5	122
CFA-133	Meadow Vole	211	281
CFA-134	Meadow Vole	167	222
CFA-135	Meadow Vole	189	252
CFA-136	Meadow Vole	217	289
CFA-137	Meadow Vole	147	196
CFA-138	Meadow Vole	302	402
CFA-139	Meadow Vole	490	653
CFA-140	Meadow Vole	166.6	222.1
CFA-142	Meadow Vole	164	218

COLUMBIA FALLS ZONE 2 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-212	Martin	465	
CF-93A	Meadow Vole	1040	1383
CF-94A	Meadow Vole	1230	1640
CF-95A	Meadow Vole	1785	2380
CF-96A	Meadow Vole	720	960
CF-97A	Meadow Vole	1720	2293
CF-98A	Meadow Vole	967	1289
CF-99A	Meadow Vole	1000	1333
CF-100A	Meadow Vole	1360	1813
CF-101A	Meadow Vole	550	700
CF-102A	Meadow Vole	1040	1384
CF-103A	Meadow Vole	600	800
CF-104A	Meadow Vole	332	442
CF-105A	Meadow Vole	545	693
CF-106A	Meadow Vole	695	926
CF-107A	Deer Mouse	522	696
CF-108A	Deer Mouse	21.0	28.0
CF-109A	Deer Mouse	525	700
CF-65A	Columbian Ground Squirrel	595	793
CF-66A	Columbian Ground Squirrel	430	573
CF-67A	Columbian Ground Squirrel	2490	3320
CF-73A	Deer Mouse	750	1000

COLUMBIA FALLS ZONE 2 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
CF-74A	Columbian Ground Squirrel	363	484
CF-75A	Columbian Ground Squirrel	3100	4133
CF-84A	Columbian Ground Squirrel	560	747
CF-85A	Columbian Ground Squirrel	1000	1333
CF-86A	Columbian Ground Squirrel	1262	1682
CF-87A	Columbian Ground Squirrel	735	980
CF-88A	Deer Mouse	824	1098
CF-89A	Deer Mouse	920	1226
CF-90A	Deer Mouse	1668	2224
CF-91A	Deer Mouse	3857	5122
CF-92A	Redtail Chipmunk	1000	1333
CFA-143	Deer Mouse	125	166
CFA-144	Deer Mouse	168	224
CFA-145	Meadow Vole	70	93
CFA-146	Meadow Vole	1010	1343
CFA-147	Meadow Vole	158	210
CFA-148	Meadow Vole	250	333
CFA-149	Meadow Vole	468	624
CFA-150	Meadow Vole	795	1060
J-1	Whitetail Deer	1100	
F-1	Whitetail Deer	1905	
F-2	Whitetail Deer	3495	
F-3	Whitetail Deer	2005	
GPA-99	Whitetail Deer	1530	

CORAM ZONE 3

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-4-1	Columbian Ground Squirrel	523.7	733.7
GPA-4-2	Columbian Ground Squirrel	772.7	1103.7
GPA-6-1	Columbian Ground Squirrel	719.3	1079.0
GPA-7-1	Columbian Ground Squirrel	544.0	805.5
GPA-12-1	Columbian Ground Squirrel	323.6	481.7
GPA-16-1	Snowshoe Hare	87.5	125.8
GPA-22-1	Columbian Ground Squirrel	752.4	1024.2
GPA-22-2	Columbian Ground Squirrel	12.4	16.9
GPA-22-3	Columbian Ground Squirrel	3215.4	4504.5
GPA-22-4	Columbian Ground Squirrel	113.4	143.9
GPA-22-5	Columbian Ground Squirrel	116.6	144.1
GPA-22-6	Snowshoe Hare	368.8	530.1
GPA-22-7	Snowshoe Hare	2053.4	2939.9
GPA-23-1	Columbian Ground Squirrel	150.0	203.7
GPA-23-2	Columbian Ground Squirrel	51.3	71.7
GPA-24-1	Columbian Ground Squirrel	5198.6	7168.1
GPA-24-2	Columbian Ground Squirrel	278.9	363.0
GPA-24-3	Columbian Ground Squirrel	571.4	771.9
GPA-24-4	Columbian Ground Squirrel	1526.3	2191.4
GPA-104-1	Whitetail Deer	840	-
CF-110A	Deer Mouse	1280	1706
CF-111A	Deer Mouse	1230	1690

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CORAM ZONE 3 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
CF-112A	Deer Mouse	854	1105
CF-113A	Deer Mouse	910	1213
CF-114A	Chipmunk	815	1086
CF-115A	Chipmunk	1470	1960
R#1	Whitetail Deer	3700	
GPA-82-1	Grouse	539.7	826.9
GPA-82-2	Grouse	4208.4	5492.9
GPA-82-3	Grouse	579.2	941.1
GPA-82-4	Grouse	1201.1	1751.4
GPA-82-5	Grouse	537.9	833.3
GPA-216	Chipmunk	6239.2	
GPA-217	Chipmunk	4941.1	
GPA-218	Chipmunk	9863.0	

Grouse Crop Contents

Collection number	
GPA-82-1	35.2
GPA-82-2	13.0
GPA-82-3	16.0
GPA-82-4	14.9
GPA-82-5	-

LAKE FIVE ZONE 4

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-2-1	Columbian Ground Squirrel	765.8	1155.1
GPA-2-2	Columbian Ground Squirrel	1153.2	1648.2
GPA-2-3	Columbian Ground Squirrel	1043.3	1514.2
GPA-2-4	Columbian Ground Squirrel	586.1	850.6
GPA-2-5	Columbian Ground Squirrel	599.0	844.1
GPA-5-1	Columbian Ground Squirrel	853.9	1245.4
GPA-9-1	Columbian Ground Squirrel	567.5	848.4
GPA-10-1	Columbian Ground Squirrel	1154.4	1685.7
GPA-10-2	Columbian Ground Squirrel	1117.0	1640.6
GPA-10-3	Columbian Ground Squirrel	61.4	85.0
GPA-10-4	Columbian Ground Squirrel	88.5	135.0
GPA-10-5	Columbian Ground Squirrel	80.3	121.6
GPA-35-1	Snowshoe Hare	1500.0	2149.2
GPA-38-1	Snowshoe Hare	48.3	845.4
GPA-38-2	Snowshoe Hare	725.0	1075.0
GPA-42-1	Chipmunk	269.5	387.5
GPA-42-2	Chipmunk	264.9	376.9
GPA-58-1	Chipmunk	1547.6	2203.4
GPA-59-1	Chipmunk	652.8	758.1
GPA-59-2	Chipmunk	611.9	820.0
GPA-64-1	Snowshoe Hare	614.3	845.8
GPA-65-1	Deer Mouse	1066.6	1280.0

LAKE FIVE ZONE 4 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-65-2	Red Squirrel	480.0	644.4
GPA-67-1	Red Squirrel	1511.0	1717.2
GPA-67-2	Bushytail Woodrat	849.6	1160.7
GPA-67-3	Red Squirrel	271.5	377.4
GPA-70-1	Chipmunk	671.4	1021.7
GPA-71-1	Chipmunk	891.8	1196.4
GPA-74-1	Chipmunk	608.1	823.7
GPA-77-1	Chipmunk	795.1	1100.0
GPA-79-1	Chipmunk	2218.7	2629.6
GPA-80-1	Chipmunk	1222.2	1767.8
GPA-91-1	Snowshoe Hare	880.0	1442.6
GPA-92-1	Snowshoe Hare	1210.0	2016.6
GPA-94	Whitetail Deer	385.0	
GPA-105	Whitetail Deer	480.0	

COLUMBIA MOUNTAIN ZONE 5

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-52-1	Chipmunk	1142.8	1538.1
GPA-53-1	Chipmunk	191.4	339.3
GPA-54-1	Chipmunk	300.0	405.4
GPA-54-2	Chipmunk	291.1	398.8
GPA-55-1	Chipmunk	1542.5	2230.7

DESERT MOUNTAIN ZONE 6

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-213	Chipmunk	911	
GPA-214	Chipmunk	315	
GPA-215	Golden Mantled Ground Squirrel	116.5	

SOUTH FORK ZONE 7

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-73-1	Chipmunk	331.2	473.3

MIDDLE FORK ZONE 8

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-8-1	Columbian Ground Squirrel	301.5	430.5
GPA-8-2	Columbian Ground Squirrel	449.4	659.3
GPA-8-3	Columbian Ground Squirrel	305.0	454.8
GPA-8-4	Columbian Ground Squirrel	309.7	437.8
GPA-8-5	Columbian Ground Squirrel	648.4	943.3
GPA-8-6	Chipmunk	454.5	666.6
GPA-28-1	Columbian Ground Squirrel	227.2	339.3
GPA-29-1	Golden Mantle Ground Squirrel	256.4	367.6
GPA-39-1	Chipmunk	142.9	200.0
GPA-95-1	Snowshoe Hare	1020.0	-
GPA-97-1	Deer	1280.0	-

NORTH FORK ZONE 9

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-1-1	Columbian Ground Squirrel	222.0	339.1
GPA-62-1	Snowshoe Hare	310.0	420.7
GPA-63-1	Snowshoe Hare	478.0	464.1
GPA-78-1	Chipmunk	462.2	649.3
GPA-81-1	Coyote	268.0	357
GPA-100	Fawn	168.0	-
CF-116A	Deer Mouse	688	914
CF-117A	Deer Mouse	210	280
CF-118A	Deer Mouse	625	910
CF-119A	Deer Mouse	640	853

HEADQUARTERS HILL ZONE 11

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-51-2	Columbian Ground Squirrel	324.0	468.8
GPA-51-3	Columbian Ground Squirrel	403.1	582.4
GPA-51-4	Columbian Ground Squirrel	472.2	686.1
GPA-51-5	Columbian Ground Squirrel	341.6	495.0
GPA-51-6	Columbian Ground Squirrel	244.7	444.0
GPA-51-7	Snowshoe Hare	252.7	384.6
GPA-51-8	Columbian Ground Squirrel	88.5	128.7
GPA-69-1	Chipmunk	620.2	844.8
GPA-69-2	Chipmunk	783.7	1133.3
GPA-33-5	Columbian Ground Squirrel	369.6	246.3
GPA-33-6	Columbian Ground Squirrel	302.0	428.9
GAP-33-7	Columbian Ground Squirrel	369.3	662.7
GPA-69	Whitetail Deer	630.0	-
PH_1	Deer Mouse	424.2	651.1
PH_2	Deer Mouse	640.4	896.6
GA-17-24	Whitetail Deer	1720.0	

BELTON HILLS ZONE 12

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-46-1	Chipmunk	351.0	456.0
GPA-46-2	Columbian Ground Squirrel	178.0	235.0
GPA-46-3	Chipmunk	290.0	373.0
GPA-46-4	Chipmunk	584.0	736.0
GPA-46-5	Chipmunk	190.0	270.0
GPA-47-1	Chipmunk	506.0	673.0
GPA-48-1	Chipmunk	859.0	1108.0
Gpa-48-2	Columbian Ground Squirrel	508.0	844.0

APGAR RIDGE AND MIDDLE FORK RANGER STATION ZONE 13

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-14-1	Columbian Ground Squirrel	931.7	1333.3
GPA-14-2	Snowshoe Hare	1784.0	2641.0
GPA-15-1	Columbian Ground Squirrel	848.6	1241.6
GPA-18-1	Columbian Ground Squirrel	507.6	719.4
GPA-18-2	Columbian Ground Squirrel	839.2	1177.9
GPA-19-1	Columbian Ground Squirrel	950.0	1250.0
GPA-19-2	Columbian Ground Squirrel	1670.0	2170.0
GPA-20-1	Columbian Ground Squirrel	738.5	1024.9
GPA-21-1	Snowshoe Hare	2046.4	2955.4
GPA-25-1	Columbian Ground Squirrel	189.9	268.9
GPA-26-2	Columbian Ground Squirrel	223.0	305.2
GPA-26-3	Chipmunk	9863.0	13333.3
GPA-26-4	Chipmunk	108.8	226.3
GPA-26-5	Chipmunk	266.6	218.1
GPA-26-6	Columbian Ground Squirrel	455.8	620.0
GPA-26-7	Golden Mantle Ground Squirrel	266.3	378.5
GPA-26-8	Golden Mantle Ground Squirrel	1298.6	1680.6
GPA-26-9	Chipmunk	494.1	6774.1
GPA-26-11	Chipmunk	6239.2	7448.9
GPA-30-1	Snowshoe Hare	1102.5	1497.9
GPA-61-1	Snowshoe Hare	579.4	844.7
GPA-66-1	Snowshoe Hare	1465.0	1888.3

APGAR RIDGE AND MIDDLE FORK RANGER STATION ZONE 13 (continued)

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-83-1	Snowshoe Hare	3100.0	4843.7
GPA-84-1	Snowshoe Hare	1140.0	1727.2
GPA-85-1	Snowshoe Hare	3450.0	5073.5
GPA-86-1	Snowshoe Hare	900.0	1343.2
GPA-87-1	Snowshoe Hare	1230.0	1835.8
GPA-89-1	Snowshoe Hare	1120.0	1723.0
GPA-90-1	Snowshoe Hare	1400.0	2258.0
GPA-93-1	Snowshoe Hare	940.0	1468.7
H-1	Snowshoe Hare	2200.0	3235.2
H-2	Snowshoe Hare	1200.0	1850.0
H-3	Snowshoe Hare	1680.0	
H-4	Snowshoe Hare	1660.0	
H-5	Snowshoe Hare	1830.0	
H-8	Snowshoe Hare	1060.0	
H-9	Snowshoe Hare	2725.0	
H-10	Snowshoe Hare	2975.0	
H-11	Snowshoe Hare	1450.0	
H-12	Snowshoe Hare	1170.0	
H-13	Snowshoe Hare	650.0	

APGAR LOOKOUT ZONE 14

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-13-1	Columbian Ground Squirrel	479.9	723.9
GPA-43-1	Chipmunk	366.6	532.2
GPA-44-1	Chipmunk	304.8	446.4
GPA-44-2	Chipmunk	213.5	318.7
GPA-60-1	Snowshoe Hare	331.5	419.4
GPA-72-1	Snowshoe Hare	425.8	577.3
GPA-75-1	Snowshoe Hare	534.9	730.1
GPA-76-1	Snowshoe Hare	585.8	787.8
GPA-57-1	Snowshoe Hare	336.1	430.1
GPA-57-2	Snowshoe Hare	1200.0	1500.0
GPA-57-3	Snowshoe Hare	234.2	324.6
GPA-57-4	Snowshoe Hare	389.0	521.8
GPA-101-1	Snowshoe Hare	1100.0	1692.3
GPA-101-2	Snowshoe Hare	680.0	1096.7
GA-18-25	Whitetail Deer	1040.0	
GNP	Whitetail Deer	124.0	

BOEHM'S BEAR DEN ZONE 15

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-57A_2	Snowshoe Hare	624.7	844.6
GPA-68-1	Chipmunk	415.3	613.5

LAKE MCDONALD ZONE 16

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-205	Snowshoe Hare	575.0	
GA-77-84	Mule Deer	2400.0	
1	Mule Deer	2140.0	
2	Mule Deer	1470.0	
3	Mule Deer	1220.0	

CAMAS CREEK ZONE 17

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-206	Chipmunk	212.5	
GPA-207	Chipmunk	115.1	
GPA-208	Snowshoe Hare	382.0	

LONEMAN MOUNTAIN ZONE 19

Collection number	Species	Fluoride, ppm	
		Unashed	Ashed
GPA-209	Columbian Ground Squirrel	470	
GPA-210	Chipmunk	367	

FLUORIDE CONCENTRATIONS IN CONTROL ANIMALS FROM VARIOUS AREAS IN MONTANA

Sample number	Species	Place collected	Date collected	Fluoride, ppm	Average ppm F⁻
GAC-1	Chipmunk Adult	6 mile	5/18/71	260.0	
GAC-29	Chipmunk Adult	Albert Creek	6/3/71	123.2	
GAC-30	Chipmunk Adult	MacDonald Pass	9/2/70	124.0	
GAC-34	Chipmunk Adult	Rattlesnake	9/18/70	50.6	
GAC-37	Chipmunk Adult	Rattlesnake	9/14/70	54.1	
GAC-40	Chipmunk Adult	MacDonald Pass	9/2/70	303.7	
GAC-59	Chipmunk Adult	Albert Creek	7/9/71	102.9	108.7
GAC-60	Chipmunk Adult	Albert Creek	7/9/71	50.0	
GAC-65	Chipmunk Adult	Albert Creek	7/9/71	122.5	
GAC-66	Chipmunk Adult	Albert Creek	7/9/71	51.5	
GAC-67	Chipmunk Adult	Albert Creek	7/9/71	53.3	
GAC-68	Chipmunk Adult	Albert Creek	7/9/71	59.6	
GAC-69	Chipmunk Adult	Albert Creek	7/9/71	60.8	
GAC-70	Chipmunk Adult	Albert Creek	7/9/71	75.7	
GAC-71	Chipmunk Adult	Albert Creek	7/9/71	92.5	
GAC-72	Chipmunk Adult	Albert Creek	7/9/71	136.3	
GAC-2	Columbian Ground Squirrel Adult	6 mile	5/18/71	105.2	
GAC-28	Columbian Ground Squirrel Adult	Albert Creek	6/3/71	146.0	
GAC-74	Juvenile	Albert Creek	7/11/71	34.6	
GAC-63	Adult	Albert Creek	7/9/71	85.6	

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FLUORIDE CONCENTRATIONS IN CONTROL ANIMALS FROM VARIOUS AREAS IN MONTANA (continued)

Sample number	Species	Place collected	Date collected	Fluoride, ppm	Average ppm F⁻
GAC-64	Columbian Ground Squirrel Adult	Albert Creek	7/9/71	128.0	
GAC-41				86.0	
GAC-42				116.0	
GAC-43				138.0	
GAC-75				126.0	
GAC-76	Juvenile			54.0	104.9
GAC-77	Adult			126.4	
GAC-78	Juvenile			132.0	
GAC-79	Adult			130.0	
GAC-80				142.0	
GAC-81				50.8	
GAC-82				77.3	
GAC-33	Deer Mouse	Rattlesnake	9/18/70	100.0	106.5
GAC-36				113.1	
GAC-31	Snowshoe Hare Juvenile	Pattee Canyon	8/1/70	48.0	41.5
GAC-32				35.0	
GAC-21A	Lepus a. Adult	Swartz Creek	11/8/70	166.0	166.0
GAC-61	L. Ground Squirrel	Albert Creek	7/9/71	95.6	66.6
GAC-62				37.6	

FLUORIDE CONCENTRATIONS IN CONTROL ANIMALS FROM VARIOUS AREAS IN MONTANA (continued)

Collection number	Species	Location	Fluoride, ppm
1		Thompson Falls	257.0
2	Mule Deer	Superior	267.0
3	Mule Deer	Superior	379.0
4	Whitetail Deer	Superior	148.5
5	Whitetail Deer	Ravalli County	90.0
6	Whitetail Deer	Marshall Creek Missoula County	135.0
8		Cameron	166.0
9		Cameron	243.0
11	Mule Deer	Swan Valley	395.0
12		Cameron	185.5
13		Cameron	191.5
14	Mule Deer	Whitehall	351.5
16		Winston	635.0
17		Thompson Falls	86.0
18		Thompson Falls	196.0
19	Mule Deer	Montana City	375.0
21	Mule Deer	Jefferson City	226.0
22	Mule Deer	Boulder	158.0
25	Whitetail Deer	Salmon Lake	210.0
26	Mule Deer	Forsythe	164.0
27	Whitetail Deer	Jordan	136.0
30	Whitetail Deer	Plains	190.0

FLUORIDE CONCENTRATIONS IN CONTROL ANIMALS FROM VARIOUS AREAS IN MONTANA (continued)

Collection number	Species	Location	Fluoride, ppm
31	Mule Deer	Thompson Falls	88.0
34		Swan Lake	115.0
35			105.0
37		Marshall Creek	395.0
38		Noxon	124.0
40		Plains	105.0
42		Thompson Falls	256.0
43	Mule Deer	Eastern	184.0
45	Mule Deer	Deep Creek	419.0

APPENDIX F

CHEMICAL ANALYSIS OF VEGETATION AND SOIL; RESULTS OF COLLABORATIVE TESTING

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METHODS OF CHEMICAL ANALYSIS FOR FLUORIDE

Vegetation

A. Conifer Needles

Upon receipt at the laboratory, conifer needles were removed from their branches and separated according to year (1968, 1969, and 1970), placed loosely in paper sacks, and dried at 90°F in a forced-draft oven.

B. Stems

Stems were cut and separated according to year, as with the needles. Stems were then chopped with clippers, placed in paper sacks, and dried in a forced-draft oven at 90°F.

C. Female Cones

Female cones were removed from the branches, chopped into small pieces, placed in paper bags, and dried at 90°F in a forced-draft oven.

D. Contents of Grouse Crops

Contents of intact grouse crops were removed from the crops, placed in paper bags, and dried at 90°F in a forced-draft oven.

E. Garden Vegetables and Grasses

Grass and fresh garden vegetables were placed in paper bags and dried at 90°F in a forced-draft oven.

F. Pollen and Staminate Cones

Pollen and staminate cones were placed in paper bags and dried at 90°F.

When dry, the sample was removed from the forced-draft oven and ground in a Wiley mill to pass a 40-mesh screen. One gram of dried, ground plant material was then placed in a nickel crucible with 0.05 g of low fluorine calcium oxide and sufficient distilled water to form a loose slurry. The slurry was then evaporated dry and charred under infrared lights. When the vegetation was charred, the crucible was placed in a muffle furnace and ashed overnight at 600°C.

After ashing, the crucibles were removed from the muffle furnace and cooled in a dessicator. When the crucibles were cool, 2 to 3 ml of distilled water was added to the crucible followed by 1 to 2 ml of 30% perchloric acid to dissolve the ash. The dissolved ash was then transferred to a 100-ml volumetric flask, and made to volume with 50% TISAB in distilled water. Fluoride activity was determined with a fluoride specific ion electrode.

The specific ion electrode was calibrated daily with standard solutions containing fluoride concentrations ranging from 0.01 ppm to 19.0 ppm. The electrode response in millivolts was plotted against fluoride concentration, and concentrations of fluoride in unknown samples were determined from the resulting curve.

Soil

Soil samples were dried in paper bags in a forced-draft oven at 90°F. When dry, 0.50 g of the soil was slurried in a nickel crucible with 0.05 g of calcium oxide and distilled water. The slurry was evaporated dry under infrared light, and the soil was ashed overnight in a muffle furnace at 600°C. The crucibles were removed from the muffle furnace and cooled in a dessicator.

The ash was dissolved in 2 ml of 20% hydrochloric acid, made to 100 ml with 50% TISAB in distilled water, and the fluoride activity was determined with a specific ion electrode.

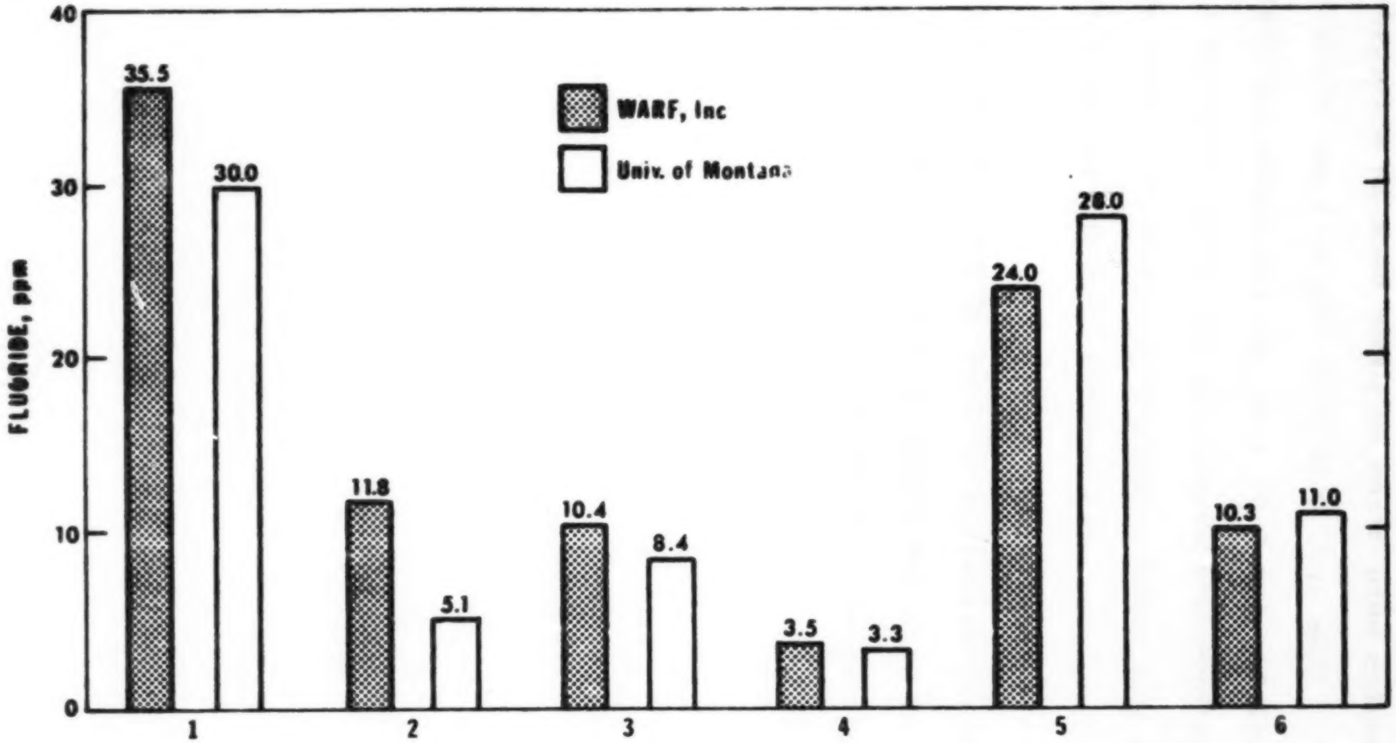

Figure F-1 Results of Pine Tissue Collaborative Analyses, University of Montana - Orion Electrode Method and WARF, Inc. - Autotechnicon Method.

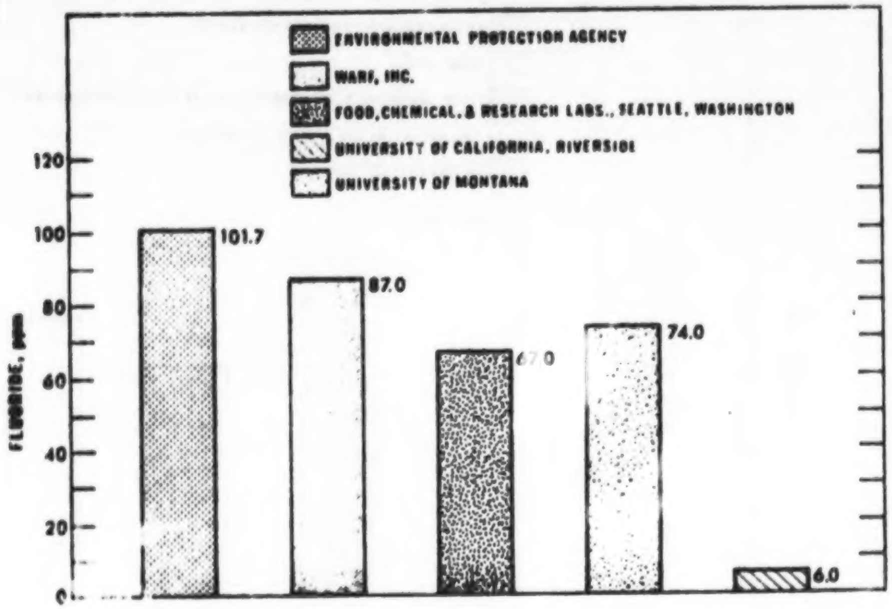

Figure F-. Results of collaborative analysis: Pinus contorta 1968 needles.

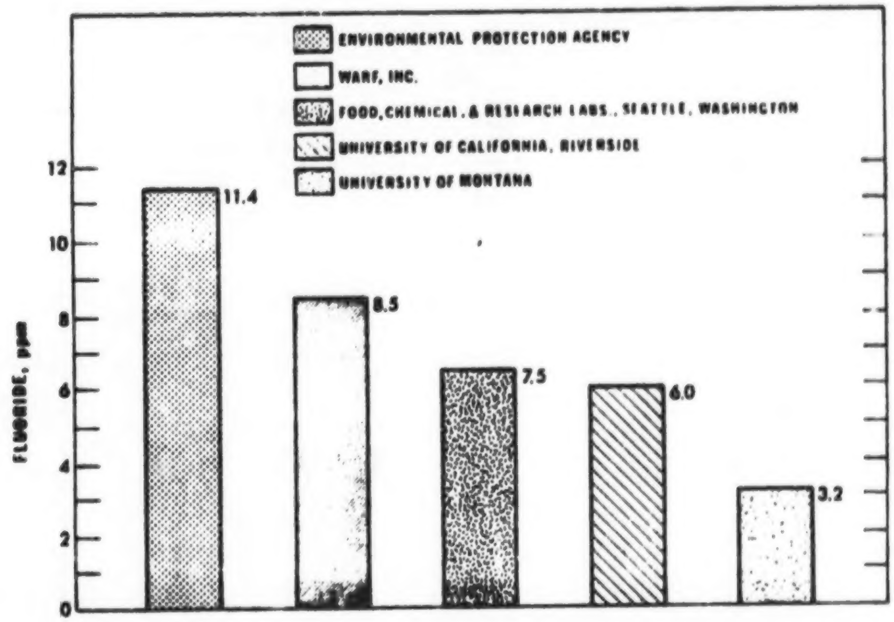

Figure F-3 Results of collaborative analysis: Pinus contora 1970 needles.

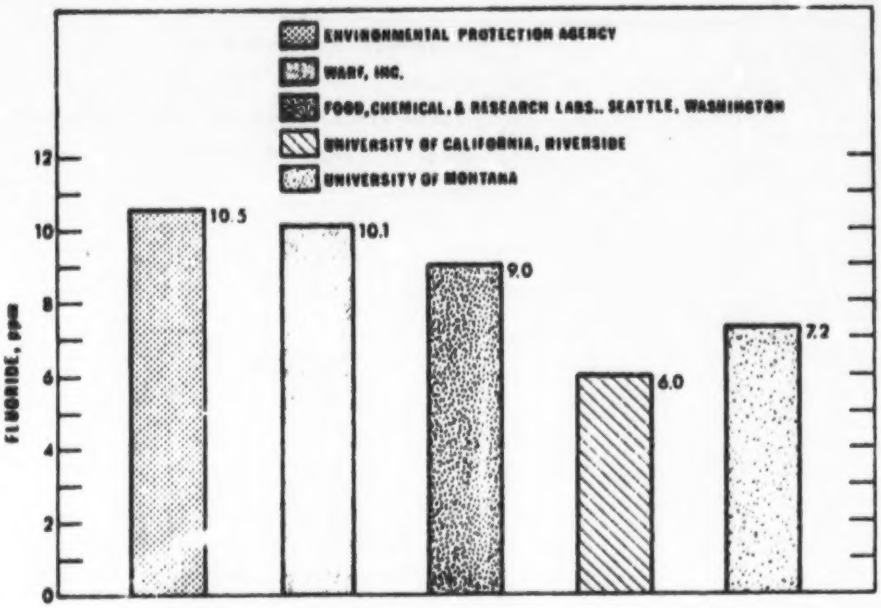

Figure F-4 Results of collaborative analysis: Pinus monticola 1968 needles.

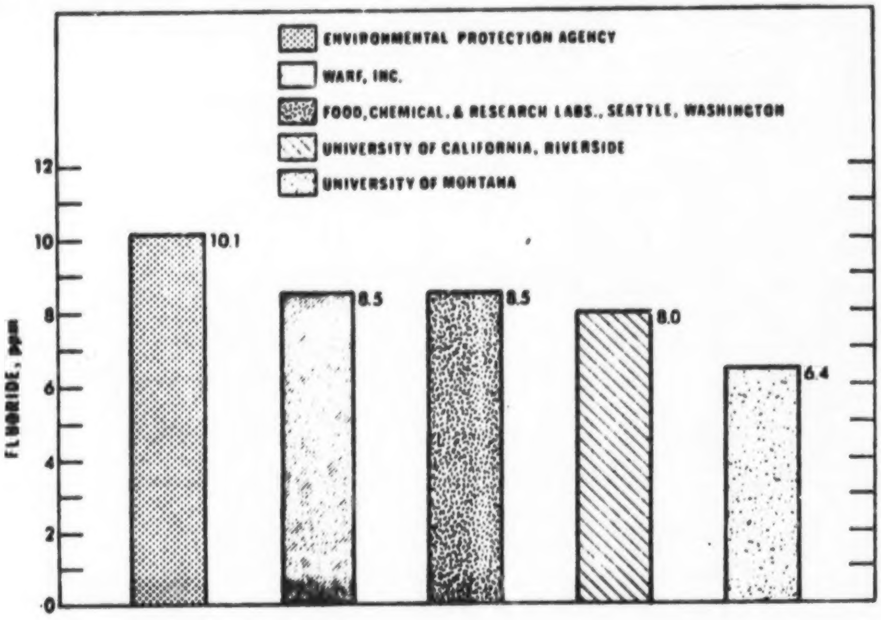

Figure F-5 Results of collaborative analysis: Pinus ponderosa 1970 needles.

APPENDIX G

CHEMICAL ANALYSIS OF ANIMAL TISSUE

CHEMICAL ANALYSIS OF ANIMAL TISSUE

Animal Bone Tissue

The whole femur bones of animals were defleshed by hand as thoroughly as possible and then boiled in Alconox for 2 hours, or until all remaining flesh was removed from the surface of the bone.

Then, depending on size, one of each pair of femurs was either sawn in half and broken into small pieces, or just broken up. The broken bones were then reboiled in Alconox and dried in a vacuum oven. When dry, the bones were defatted by boiling with at least six changes of petroleum ether and again dried in a vacuum oven.

The dry, defatted bones were then ground in a Wiley mill to pass a 20-mesh screen, weighed into a nickel crucible, and ashed at 600°C overnight. The crucibles were removed from the muffle furnace and cooled in a dessicator; the ash was dissolved in 2 ml of 20% hydrochloric acid. The dissolved ash was made to 100 ml with 50% TISAB in distilled water and the fluoride activity was determined with a specific ion electrode.

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The specific ion electrode was calibrated daily with standard solutions containing fluoride concentrations ranging from 0.01 ppm to 19.0 ppm. The electrode response in millivolts was plotted against fluoride concentration, and concentrations of fluoride in unknown samples were determined from the resulting curve.

APPENDIX H

PREPARATION OF CONIFER NEEDLES FOR HISTOLOGICAL STUDY

HISTOLOGICAL TECHNIQUES

Cross and longitudinal sections of conifer needles manifesting tip necrosis were prepared in the following manner. Two-millimeter sections were removed from the conifer needles in the transition zone, where the necrotic portion abuts the green portion of the diseased needle. The 2-mm sections selected for histological studies, therefore, encompass approximately 1 mm of the green tissue, 1/4 mm of the yellow tissue, and 3/4 mm of the brown, necrotic tissue. Six to eight 2-mm sections were removed from the needle samples collected from any given sampling site.

The selected pine sections were placed in shell vials containing FAA (formaldehyde acetic acid and alcohol), aspirated actively for 30 minutes, and left under vacuum for 24 hours. After the tissues were fixed in FAA for 24 to 48 hours, the materials were dehydrated in a TBA (tertiary butyl alcohol) series of 50% to 100% (Johansen, Plant Microtechnique, 1940) and then placed in 52°C melting paraffin. After 24 hours and two changes in the 52°C paraffin, the needle tissues were placed in 56°C paraplast and boated in Coors 10H porcelain boats. Three to four needle sections from each of the paraffin blocks were removed, mounted on hardwood blocks, and trimmed in preparation for microtoming.

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Needle sections were cut at 8 to 12 micra with an American Optical 820 rotary microtome and adhered to the microscope slides with Haupts adhesive and 2% formalin solution. After sections were dried on the slides for 48 to 64 hours, the slides were ready for the staining series. They were put into five changes of xylene to deparaffinize the tissue and then hydrated with the normal alcohol and water series (i.e., 100% ETOH to 30% ETOH). The first stain used was Feulgens nuclear stain, and after the destaining, the slides were put up through the alcohol series 30% to 90% ETOH and counter stained with fast green. After the fast green was destained in 80% ETOH, the slides were continued up through the dehydrating series (90% to 100% ETOH) and put through five changes of xylene, before cover slips were placed over the sectioned and stained conifer needle tissues. The cover slips were adhered to the slides with Harleco synthetic resin and left to dry on heating plates (30°C) for 24 hours.

Tissue pathology manifested in the conifer needle sections was studied with a phase microscope, and photomicrographs were taken with 35-mm high-speed tungsten Ecktachrome.